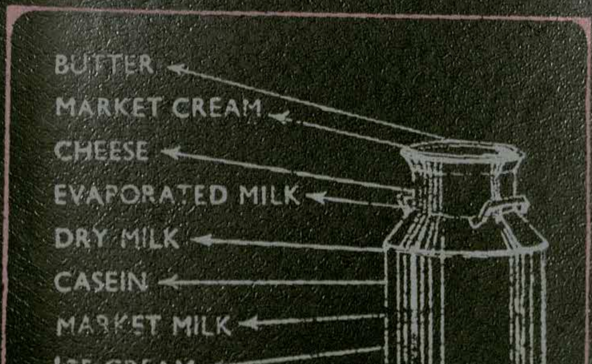
MILK AND MILK PRODUCTS

CLARENCE HENRY ECKLES
WILLES BARNES COMBS
HAROLD MACY



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MILK AND MILK PRODUCTS

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Prepared for the Use of

AGRICULTURE COLLEGE STUDENTS

BY

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FOURTH EDITION

UBS Publishers' Distributors Ltd
8/1-B, Chowringhee Lane, Calcutta-700 016
Ph:212451, 249473

TATA McGRAW-HILL PUBLISHING COMPANY LTD.
Bombay—New Delhi

MILK AND MILK PRODUCTS

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T M H EDITION-1973
Reprinted—1976
Reprinted—1979
Reprinted—1980
Reprinted—1982
Reprinted—1984
Reprinted—1986
Reprinted—1988

Reprinted in India by arrangement with
McGraw-Hill Inc., New York

This edition can be exported from India only by the publishers,
Tata McGraw-Hill Publishing Company Limited.

Acc no-16765

PUBLISHED BY TATA MCGRAW-HILL PUBLISHING COMPANY LIMITED
AND PRINTED AT PEARL OFFSET PRESS PRIVATE LIMITED
5/33, KIRTI NAGAR INDL. AREA, NEW DELHI-110015.

PREFACE TO THE FOURTH EDITION

Developments in the dairy industry during the Second World War and in the postwar period have been important enough to justify a revision of a considerable amount of material in "Milk and Milk Products." Certain chapters have been completely rewritten to bring them up to date in subject matter, statistical material, and illustrations. Some new material which was not included in earlier editions has been added.

We are happy to acknowledge the assistance of Dale E. Butz in the revision of Chapter I and of Elmer Thomas in the revision of Chapters VII and XV. We wish to record our gratitude to the many individuals and companies who have graciously provided new illustrative material, constructive criticism, and advice.

WILLES BARNES COMBS
HAROLD MACY

ST. PAUL, MINN.
February, 1951

PREFACE TO THE FIRST EDITION

In most colleges of agriculture an introductory course in dairying is given to students during the first or second year. One of the difficulties experienced in planning the subject matter for a beginning course of this kind is the fact that few of the students in agriculture have planned their line of specialization at the time they are enrolled in it. The instructor realizes that within the group are some that will later become dairy specialists, while for many it is the only course dealing with the dairy industry that they will take. The selection of subject matter would be much easier if these groups were segregated. As it is, the course usually offered is something of a compromise between presenting the fundamentals of the subject and giving a general course conceived to be of the greatest value to students expected to engage in farming operations.

Considerable variation exists in different colleges as to the subject matter selected. Some undertake to cover the entire field of dairying in the form of a survey course including milk production, the nature of milk, and the manufacture of dairy products. The larger number, including ourselves, find the results more satisfactory when a portion of the field is covered more thoroughly.

The material included in "Milk and Milk Products" is the result of considerable experience by the authors with a course of this kind. In the past we have presented the subject matter by a combination of lectures, textbook assignments, and library references.

The need has been felt for a text of college grade in which some knowledge of chemistry on the part of the students is assumed. Most of the students enrolled in an introductory course in dairying have had some elementary chemistry either in high school or college, but the majority have not had elementary bacteriology. For this reason a brief account is given of the nature and activities of bacteria and other microörganisms important in dairying.

We have found it advisable to dwell rather intensively on the composition and properties of milk and the factors which influence these characteristics. In this connection a discussion of the microbiology of milk is presented because of the important relationship of microörganisms to changes in the composition and properties of milk and its products. When these fundamental facts have been presented, it is possible to point out the bearing which they have upon the various milk products and the processes which are involved in their manufacture. Such an understanding of the fundamental nature of milk and the forces which are active in its alteration or processing for the preparation of milk products, is essential if one is to gain an insight into the true nature of the phenomena involved in the modern methods of dairying.

Students, as well as those engaged in dairying in a commercial way, seem to experience special difficulties in solving certain practical problems with which they are confronted when the application of simple mathematics is involved. Experience has taught the practical importance of using material of the type presented in the chapter entitled "Dairy Arithmetic." Each problem introduced represents a type confronted in practical dairy operations.

In view of the fact that many students take but one course in dairying, emphasis is also placed upon the sanitary production of milk and the value of dairy products in the human diet.

In the preparation of the manuscript the authors naturally contributed those portions which come within the field of their specialization. The whole has been combined and revised by them until no differentiation of authorship is made concerning any particular portion.

The authors wish to acknowledge their indebtedness to Dr. Lloyd M. Thurston, a former colleague, who assisted in the preparation of portions of the material, especially Chapters VII and VIII.

THE AUTHORS

ST. PAUL, MINN.
September, 1929.

CONTENTS

PREFACE TO THE FOURTH EDITION v

PREFACE TO THE FIRST EDITION vii

CHAPTER I

INTRODUCTION 1

Dairy industry prior to 1850—Dairy industry after 1850—Importance of the dairy industry—Milk production and utilization—Market milk—Butter—Cheese—Concentrated milk—Ice cream—By-products—Demand for milk and milk products—Per capita consumption of dairy products—International trade.

CHAPTER II

THE CONSTITUENTS OF MILK 21

General characteristics of milk—Chemical composition—Water in milk—Fat of milk—Structure and nature of fat of milk—Size of fat globules, importance—Composition of milk fat—Volatile and non-volatile groups—Properties of milk fat—Factors influencing the composition of milk fat—Proteins of milk—Casein—Albumin—Lactalbumin—Other proteins—Lactose—Action of bacteria on lactose—Lactose in dairy manufactures—Ash or mineral matter—Uses of mineral matter—Minor constituents of milk—Phospholipids—Cholesterol—Pigments—Enzymes of milk—Vitamins—Gases—Non-protein nitrogenous substances.

CHAPTER III

FACTORS INFLUENCING THE COMPOSITION OF MILK 46

Importance of variations—Nature of variations—Species of animal—Breed—Stage of lactation—Individual variations—Seasonal variations—Variations, milking to milking—Interval between milkings—First and last milk—Fatness of cow—Feed of cow—Effects of feed upon milk.

CHAPTER IV

PROPERTIES OF MILK 68

Physical state of milk—Chemical reaction—Specific gravity—Taste and odor—Color of milk—Freezing point—Effect of freezing on milk—Specific heat—Boiling point—Effect of heat on milk—Viscosity of milk—Adhesiveness—Effects of enzymes on milk—Effect of acids on milk.

CHAPTER V

MILK AND DAIRY PRODUCTS AS FOOD 82

Food requirements—Water—Carbohydrates and fats—Proteins—Minerals or ash—Food accessories, vitamins—Requirements of a suitable food—Economy of milk as a food—Milk as a source of protein—Milk as a source of energy—Relation of richness of milk to food value—Milk for the child and adult—Pasteurization—effect on nutritional value—Food value of other dairy products—Butter—Cheese—Ice cream—Concentrated milks—Skim milk and buttermilk—Fermented milk.

CHAPTER VI

MICROÖRGANISMS 102

Bacteria—Yeasts—Molds—Naming of microörganisms—The growth of microörganisms—Food supply—Moisture—Atmosphere—Chemical and physical environment—Preservatives—Light and Electricity—Thunder storms and the souring of milk—Concentration of medium—Temperature—Products of growth—Enzymes—Decomposition products—Pigments, toxins—Methods of counting microorganisms—Sources of the microörganisms in milk, udder, exterior of cow's body, air and utensils, milker or handler—Fermentations of milk—The "germicidal" period—Period of souring—Neutralization period—General decomposition—Specific fermentations of milk—Souring—Souring and gassiness—Aroma and flavor—Proteolysis—Alkali production—Ropiness—Sweet curdling—Butyric acid fermentation—Bitter flavor—Alcoholic color—Miscellaneous fermentations—Transmission of disease through milk—Determining the wholesomeness of milk.

CHAPTER VII

THE BABCOCK METHOD FOR DETERMINING FAT IN MILK AND CREAM . . 132

Historical—General procedure—Principles of the test—Testing whole milk, measuring the sample, adding the acid, centrifuging, reading the test—Defective tests—Testing cream—Variations from milk procedure, why cream samples are weighed, elimination of meniscus, size of samples taken, procedure—Details of test bottles and balances, the milk bottle, the cream bottle, the cream balance—Centrifuges.

CHAPTER VIII

COMMON DAIRY PROCESSES 151

Cream Separation—Historical—Basic principle of separation—Gravity creaming—Shallow-pan, deep-setting, water-dilution methods—Centrifugal creaming—Early developments—Introduction in United States—Principle of centrifugal separation—Construction of a centrifugal separator—Control of richness of cream—Factors governing fat percentage, speed, temperature, richness of milk, rate of inflow, flushing—Slime—Extent of vari-

ations under practical conditions—Efficiency of the separator—Factory separator—Effect of separation upon microörganisms—Straining, filtration, and clarification of milk—Pasteurization of milk—Relation to microörganisms—Methods of pasteurization, the holding system, the high temperature-short-time system—Construction of holding pasteurizers—Construction of high temperature-short-time pasteurizers—Cooling milk or cream—In-the-bottle pasteurization—Electrical pasteurization—Homogenization of milk—Types of homogenizers—Action of the homogenizer—Use of the homogenizer—Reconstructed milk and cream—Emulsification—Soft-curd milk—Vitamin fortification of milk.

CHAPTER IX

MARKET MILK 203

Stages of development—Complexity of the problem—Necessity for public supervision—Production of market milk; clean, healthy cows; proper construction of barns; small-mouth pail; clean, healthy people; clean, sterilized utensils; the milking machine and separator; prompt cooling; prompt delivery—Certified milk—Transportation of milk—Delivery of milk—Purchase of milk—The milk plant—Problems of the distributor—Health control of milk supplies—Control measures: supervision in the small town; supervision in the large city—Pasteurization as a health-control measure—Grades of milk.

CHAPTER X

THE MANUFACTURE OF DAIRY PRODUCTS—BUTTER 225

Historical—Effect of the cream separator—Status of farm butter—Composition of butter—Processes involved—Separation of milk—Cream for butter making—Off-flavors in cream—Cream grades and grading—Neutralization of cream—Pasteurization of cream for butter making—Starters—Cream ripening—Butter color—Churning—Nature of churning—The churn—The combined churn and worker—Churning procedure—Factors influencing churning: temperature, composition of fat, influence of size of fat globules, acidity, viscosity of cream, richness of cream, fullness of churn, speed of churn—Fat losses in buttermilk—Difficult churning—Overrun in butter making—Salting butter—Working butter—Continuous churn—Marketing butter—Market terms—Market grades—Butter defects—Farm butter making.

CHAPTER XI

THE MANUFACTURE OF DAIRY PRODUCTS—CHEESE 266

Historical—Nature of cheese—Classification of cheese—Composition of cheese—Milk for cheese making—Manufacture of hard cheese—American Cheddar cheese: equipment required; process of manufacture; curing; forms; market grades; defects—Emmental or Swiss cheese—Roquefort or Blue cheese—Brick

cheese—Soft cheeses: Limburger cheese, Camembert cheese, Cottage cheese, Cream cheese—Process cheese—Cheese spreads—Cheese foods.

CHAPTER XII

THE MANUFACTURE OF DAIRY PRODUCTS—ICE CREAM 290

Historical—Definition and classification—Ingredients used—Quality of dairy products—Sweeteners—Stabilizers—Flavoring materials—Preparation of the ice-cream mix—Calculation of the mix—A problem in calculating the mix—Pasteurization of the mix—Homogenizing the mix—Aging the mix—Freezing the ice cream—Bulk ice cream—Packaged ice cream—Brick ice cream—Preparation of individual forms—Quality of ice cream—Ice-cream defects—Distribution of ice cream—Ice-cream making in the home—Microbiology of ice cream.

CHAPTER XIII

THE MANUFACTURE OF DAIRY PRODUCTS—CONDENSED MILK, DRY MILK, MILK BY-PRODUCTS 313

History of condensed milk—Terms applied to concentrated milks—Composition of condensed milk—Properties of condensed milk—Method of condensing milk—The vacuum pan—Standardization of condensed milk—Cooling of condensed milk—Use of condensed milks—Defects in condensed milks—Marketing of condensed milk—Dry milk, historical—Methods of manufacture: the spray process; the drum process; atmospheric-drum process; vacuum-drum process—Types of dry milk—Composition of dry milk—Properties of dry milk—Use of dry milk—Malted milk—Defects in dry milk—Marketing of dried milk—Reconstituting dry milk—Microbiology of condensed and dry milk—Milk by-products—Skim milk as a by-product, for animal feed, for human food, other uses—Buttermilk—Commercial products from buttermilk—Whey and whey products—Manufacture of casein—Uses for casein—Fermented milk beverages.

CHAPTER XIV

DAIRY ARITHMETIC 352

Calculations of interest to the producer: determining pounds of fat in milk; finding the true average fat percentage; setting the price of milk; determining the value of cream sold by the gallon; farm separation problems; determining the most profitable market—Selling milk or cream—Standardizing milk and cream—Calculations pertaining to butter—Calculating the composition of the ice-cream mix.

CHAPTER XV

MISCELLANEOUS TESTS 368

Sampling milk and cream, how to take a sample, sampling frozen milk or cream, sampling churned milk or cream, sampling sour milk or cream, preserving the sample—The composite sample: equipment required, the sample container, taking the sample, preservatives for composite samples, composite cream samples, care of the composite sample, testing composite sample—Modified Babcock tests, testing skim milk, buttermilk, whey, cheese, ice cream, chocolate milk, condensed milk—Testing homogenized milk—The calibration of Babcock testing glassware—Roese-Gottlieb fat analysis—The determination of specific gravity—The lactometer—Calculation of total solids—The determination of acidity, use in dairy manufacturing, details of test—Determination of hydrogen-ion concentration—The sediment test—Sediment test for dairy products—Analyses of butter at factory, modified Kohman test, sampling, moisture, fat, salt and curd determinations—Detection of mold in cream and butter—Detection of added water by freezing-point determination—Total solids determination—Marschall rennet test—Methylene blue test for milk quality—Resazurin test—Alcohol test—Fermentation test—Tests for heated milk—Storch test—Arnold or Guaiac test—Phosphatase test—Test to distinguish oleomargarine from butter.

APPENDIX 40

Methods for bacteriological analysis of milk—Roese-Gottlieb method for fat determination (Official A.O.A.C.)—Babcock method for fat determination (Official A.O.A.C.)—Milk producer—Distributor inspection form—Specific gravity and weight per gallon of milk and cream—Conversion table of standard weights and measures—Table for calculating total solids in milk from specific gravity and fat percentage—Table for determining the total solids of sweet and sour cream buttermilk from the lactometer reading—Conversion table Fahrenheit to Centigrade—Molecular weights of acids, bases, and salts and quantities necessary for tenth-normal solutions—Per capita consumption of dairy products—Market grades of creamery butter—Tentative U.S. standards for grades of American Cheddar cheese—Specific grading requirements for non-fat milk solids.

INDEX 431

CHAPTER I

INTRODUCTION

The domestication of cattle occurred between 6,000 and 10,000 years ago. Not much is known about the history of this period, but men probably hunted cattle as wild animals prior to the time that they were domesticated. The oldest written records of the human race are found in the Sanskrit of ancient India. These records date back nearly 6,000 years, but milk had already become an important article of food. In fact, the cow was so important to these early peoples of central Asia that wealth was measured in numbers of cattle. Later the cow was made a sacred animal and is still so considered by a part of the population of India.

The cow was also worshipped in Babylonia and in Egypt about 2000 B.C. Hathor, the goddess who watched over the fertility of the land, was depicted as a cow. Over 50 references to cows and milk are found in the Old Testament and the promised land was described as "a land flowing with milk and honey."

The soldiers of Genghis Khan, the Mongol emperor who conquered Asia and a large part of Europe in the thirteenth century, carried dried milk as a part of their ration. Cheese was an important part of the food supply carried by the vikings in their voyages which carried them to the shores of all northern Europe and even across the Atlantic.

From these early days to the present, the cow has continued to be the servant of man, and her importance as a source of food has not been diminished by the thousands of years which have passed. The first settlers in the New World made the mistake of not taking cattle with them. For example, the *Mayflower* did not bring cattle, and as a result of the lack of suitable food, especially milk, the death rate was very high. In fact, nearly one-half of those who came in the *Mayflower*, including every child under two years of age, died during the first winter on this continent. This mistake was recognized, and afterward the

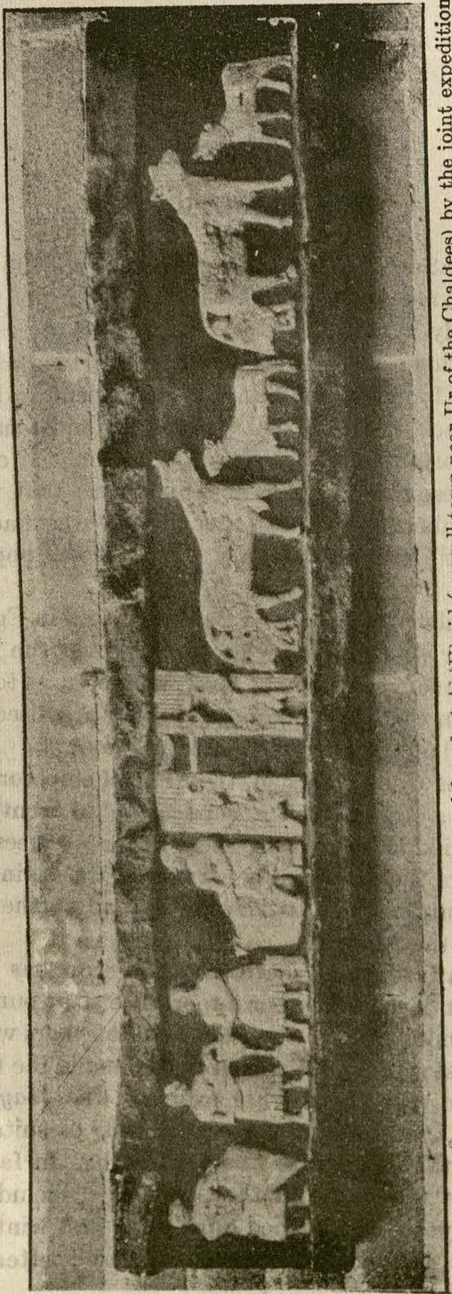

FIG. 1. A dairy scene about 3500 B.C. A panel found at Al 'Ubaid (a small town near Ur of the Chaldees) by the joint expedition of the British Museum and the Museum of the University of Pennsylvania. Note the milk containers, the strainers, and the method of milking. (*Courtesy of the Museum of the University of Pennsylvania.*)

governor ordered that one cow and two goats should be brought over for each six people. Later pioneers remembered this lesson as they pushed the frontier toward the West. The settlers and their wagons were always followed by two or three cows.

The Dairy Industry Prior to 1850. For over 225 years following the first settlements in America very little change took place in the methods of producing milk or in the manufacture of dairy products. Most of the population lived on farms or in small villages, and each family depended upon its own cows for the family milk supply. Nearly all the cows freshened in the spring or early summer, and an abundance of milk was available as long as the pastures were good. Many of the cows completed their lactation periods in the fall, and very little milk was available for human consumption during the winter months. Oftentimes cattle became so weak from lack of feed during the winter that they had to be helped to their feet and sometimes, actually starved to death.

During the summer the surplus milk was manufactured generally into butter or cheese on the farms having several cows in milk. The market prices for these products during the summer season, if any market were available at all, were ridiculously low. In the winter, fresh butter was not available on the market at any price. The surplus butter made in the summer was packed largely in firkins and covered with brine. It was stored in cellars or springhouses and constituted the chief source of butter for winter use. People were accustomed to using butter with a more or less rancid and old flavor. The product sold for table use 100 years ago would be rejected entirely at present except for industrial uses.

Cheese manufactured in the home during this period was generally far superior in quality to the butter since cheese was easier to keep under the rather primitive storage conditions. Probably much of the cheese represented a grade equal to that of cheese now on our markets. Between 1830 and 1850 certain farming sections in Vermont and New York began to develop as centers of production for surplus butter and cheese. These products were marketed in the rapidly expanding cities of the Northeast.

Keeping cows within city limits presented many difficulties as the cities became larger centers of population. Feed supplies had to be shipped from the country areas, and ordinances regarding dairy barns became more and more strict. Gradually farmers within easy driving distance began delivering milk over regular routes in the cities. This was the beginning of the fluid milksheds which surround our large cities today. Previous to 1850, however, most milk was necessarily produced within a few miles of where it was consumed because of the lack of suitable means of transportation and refrigeration. Generally speaking, the period prior to 1850 was characterized by a gradual growth in the dairy industry. The development was not spectacular, but the stage was set for the many changes which were to take place in the years to follow.

The Dairy Industry after 1850. The middle of the nineteenth century is a convenient point to set as marking the beginning of modern dairying. More changes have been made during the past 100 years than in all the previous 60 to 100 centuries since cattle were domesticated. When one observes a modern creamery, ice-cream factory, fluid-milk bottling plant, condensary, or dry-milk plant, he should appreciate that the development of these modern factories has occurred, to a very large degree, within the past 30 years. Among the many factors which have played important roles in the evolution of the modern dairy industry, the following may be mentioned:

1. *The Factory System.* One of the outstanding developments following 1850 was the introduction of the factory system. In 1851, Williams in New York began the manufacture of cheese under the factory plan. Within a few years, making cheese was transformed from a farm to a factory industry. The factory system was not applied to butter making until 1871 and did not make such rapid progress in taking over the industry as in the case of cheese. Now, however, practically all the butter and cheese on the market is of factory origin. Pasteurizing and bottling plants for fluid milk were put in operation in large cities, and in many cases milk dealers took over the processing and delivery functions formerly performed by the farmer producers. In some of the smaller markets, however, much of the milk for fluid consumption is still processed and delivered directly by the producers.

2. *Improved Machinery.* The development of improved machinery has had much to do with the growth of the dairy

industry. Modern machinery has made it possible to increase greatly the capacity of plants for handling milk or milk products. The improvement in machinery coupled with the introduction of the factory system has enabled the dairy industry to insure better quality and more standardized products for sale to consumers. Such devices as the cream separator, the milking machine, the pasteurizer, the combined churn and workers, mechanical can and bottle washers, condensing and drying equipment have all contributed to a more efficient dairy industry. New processes and new equipment designs are constantly being developed and improved in an effort to increase the sale of dairy products or improve the efficiency of existing operations.

The cream separator was introduced about 1880. This machine probably had a greater effect on the dairy industry than any of the other mechanical devices invented during the past century. With this new device, milk could be separated on the farm or in the factory and much higher quality of dairy products resulted. Losses of milk fat were less under this method of skimming, and some of the milk fat lost in cheese making could also be recovered by separating the whey.

Mechanical refrigeration, which began to come into practical use between 1880 and 1890, has had far-reaching effects upon the marketing and distribution of dairy products. Milk, cream, and dairy products such as butter, ice cream, cheese, and certain concentrated milks must be kept under refrigeration until delivered to the consumer or used in the factory. Mechanical refrigeration is now used at all stages in the production and marketing of milk and milk products. It is used in cooling milk and cream on the farm. Mechanically refrigerated storage rooms are standard equipment in milk plants. A modern ice-cream plant which might have required hundreds of tons of ice to operate 50 years ago may manufacture, store, and transport ice cream today without the use of a single pound of ice. Mechanical refrigeration and dry ice have replaced ice in many instances. However, ice is still used as a refrigerant during the delivery of fluid milk and cream. Refrigerator cars also facilitate the shipment of dairy products over long distances.

3. *Transportation.* In 1850 the regular shipment of milk by railroad was begun with the establishment of special milk trains. Further advances have been made by the introduction of tank

cars and tank trucks for milk transportation. By means of such equipment, milk is shipped for distances as great as several hundred miles with very little or no loss in quality. Cream or other products are not so perishable or so bulky as milk and are often moved thousands of miles before they are processed, stored, and consumed.

4. *Economic Factors.* Prominent among the economic factors affecting the dairy industry is the rapid growth of city population. The division of population into rural and urban categories in the census of 1850 was made on a different basis than the one used in later years. For this reason the figures for 1880 are the earliest available for comparison with the federal census of 1940. In 1880, over 71 per cent of the population was classed as rural, but by 1930 this group had declined to 43.8 per cent. During the 1930's there was a new movement of population to farms, and the proportion of the total population living in rural areas actually increased. This trend was reversed after 1935 and 41.5 per cent of the population was classed as rural in 1948. Only a part of the population listed as rural is actually engaged in farming since this category also includes many rural non-farm residents. It is estimated that in 1948 only slightly over 27,000,000 people (or 18.9 per cent of the total population) were actually engaged in farming.

This shift in location and occupation of the population has had a tremendous effect upon the location and organization of the dairy industry. Large milksheds have developed around the metropolitan areas to supply the urban consumers with the needed quantities of fresh fluid milk and cream. Other regions, with natural advantages for dairy production such as favorable climate and adequate feed supplies, have developed into specialized, dairy-product manufacturing areas. Levels of living have gradually been rising over the years, and more dairy products have been included in the diet of the American people. This increase in demand, coupled with the growing percentage of non-farm population, opened the way for a great expansion in the dairy industry. In the processing and manufacturing of most dairy products, the economies of larger units are very great, and the tendency is toward the development of relatively large plants. Large national dairy corporations and cooperative associations have assumed an important role in the processing and marketing of dairy products. As the large organizations developed, emphasis was placed on specialized plants such as the centralizer creamery. This was followed by the establishment of large diversified plants, allowing much more flexibility in the use of milk supplies. If a plant is equipped to produce several products, the output can be shifted from one product to another in order to take advantage of favorable price relationships.

Selling in central markets was at one time very common for most dairy products, and future markets developed in many lines. Recently the trend has been toward more direct shipments from the processor to the wholesaler or retailer. The growth of chain stores and large integrated sales organizations has affected greatly the channels through which dairy products move from the producer to the consumer. Such organizations either buy or manufacture the products in large quantities, perform all the necessary marketing services, and sell the finished product to consumers.

The growth of the dairy industry has been accompanied by an expansion of governmental regulations and controls relating to both production and marketing of the products. Strict sanitary regulations have been adopted at the local, state, and federal level. Grades and quality standards as well as minimum legal standards of composition for various products have been established. State milk control boards have been established in many states, and in some places both minimum farm and resale prices of milk are set by state authorities. In other areas, the milk control boards concern themselves primarily with checking milk-fat tests, weights, and payments to farmers and are not concerned with prices paid or received. The federal government has also taken an active interest in milk marketing during recent years. The minimum prices for milk delivered to many of the larger cities in the United States are now determined by the provisions of federal milk marketing orders. The number of markets operating under such arrangements has continued to grow, and several states also administer and supervise similar orders in local markets within the state.

5. *Research and Scientific Investigation.* Another factor of tremendous significance in the development of the dairy industry in the United States since 1850 is scientific investigation. It is not too much to say that science, especially through the activities

of the state agricultural colleges and experiment stations as well as the laboratories of federal agencies, has revolutionized the dairy industry. Many of the large dairy organizations as well as the Quartermaster Corps of the U.S. Army employ highly trained research personnel to work continuously on the improvement of dairy products and the development of new products or uses. Similarly, manufacturers of dairy equipment improve or perfect new or more efficient equipment.

Scientific study of feeding and breeding has made possible a tripling of milk production per animal unit. Bacteriology has laid a foundation of knowledge upon which are built the methods to be followed in producing, processing, and handling milk and its products for human food. Regulations for the supervision of milk supplies for cities as well as modern methods of sanitary milk production are based on the findings of the bacteriologist.

Chemical, physical, and nutritional research on milk and its products has been particularly significant. Out of such studies, for example, have come the Babcock test and the important facts concerning the use of milk in the human diet. The Babcock method for the rapid determination of fat in milk, first published in 1890, has been of inestimable value to the industry. The introduction of this test made it possible to buy and sell milk on a milk-fat basis; to detect unprofitable cows in the herd; to detect losses of fat in skim milk, buttermilk, and whey; to assist in detecting adulteration of milk by watering or skimming; and to carry on research on a scale never before possible. Scientific discoveries in the field of nutrition have resulted in far-reaching developments, especially in connection with the use of milk for human food. The dissemination of facts concerning the value of milk in the diet and the availability of ample supplies of fresh, wholesome milk have aided greatly in expanding the use of milk and milk products in the diet. The research workers have also sought and found many new uses for vast supplies of by-products of factory operations such as skim milk, buttermilk, and whey.

6. *Improved Livestock.* A few improved cattle had been brought to the United States prior to 1850. However, the number was so small and public interest in them so slight that this importation had no noticeable effect on the cattle population of the country. The foundation stock from which most of our cattle have descended was imported between 1860 and 1885.

Representatives of the breed associations and members of the extension service have encouraged farmers to strive for higher production per cow. Dairy-herd-improvement and cow-testing associations have been organized in many sections of the country for this purpose. Technicians from these associations make periodic tests of the milk from individual cows and assist the farmer in improving his herd. During the last few years many artificial-breeding associations have been organized in the major milk-producing regions. It is possible that this method of breeding may ultimately increase the production per cow since only the better bulls are used by the breeding associations. As a result of better breeding and feeding, the average production of dairy cows in typical dairy herds of the United States is now more than double that of 1850. Data on milk production per cow are not available for the earlier years, but since 1910 there has been an upward trend in the average production per cow in the United States. Population is still moving upward, but this increase in production per cow has enabled the dairy farmers of the nation to supply a larger amount of milk per capita from

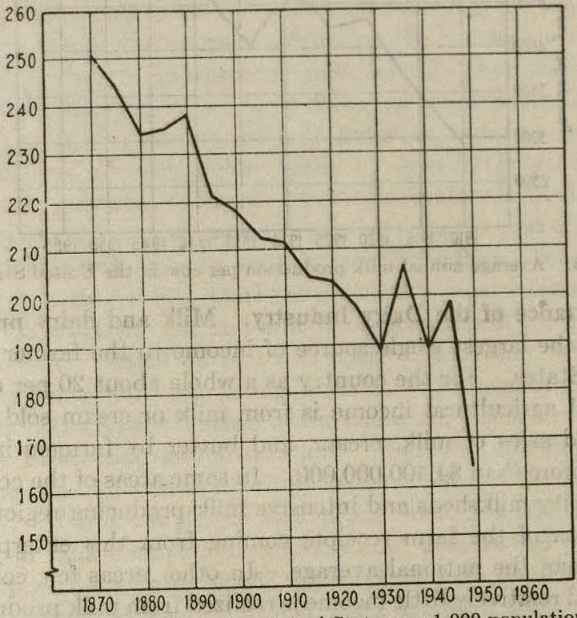

FIG. 2. Dairy cows in the United States per 1,000 population.

considerably fewer cows. In 1870 there were about 250 cows per 1,000 population or 1 cow for each 4 people. In 1949 the consumers were supplied with greater quantities of milk and milk products, but there were only 160 cows per 1,000 population or 1 cow for each 6 people.

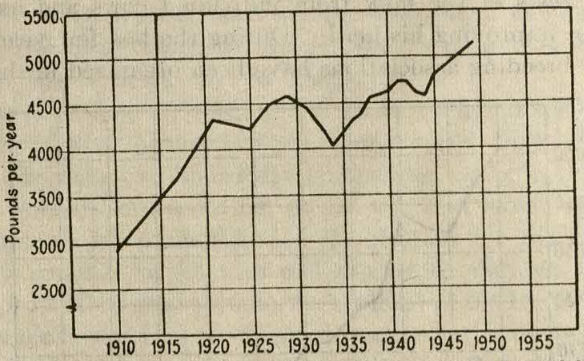

FIG. 3. Average annual milk production per cow in the United States.

Importance of the Dairy Industry. Milk and dairy products rank as the largest single source of income to the farmer of the United States. For the country as a whole about 20 per cent of the total agricultural income is from milk or cream sold. The combined sales of milk, cream, and butter by farmers in 1948 totaled more than $4,400,000,000. In some areas of the country, such as city milksheds and intensive milk-producing regions, the proportion of the farm receipts coming from this enterprise is higher than the national average. In other areas few cows are kept, and relatively little income is realized from milk production.

Approximately one-fourth of the total pounds of food consumed per capita in the United States each year is made up of milk and other dairy products. Milk is also very important from a nutritional standpoint since it contains nearly all the essential food constituents required in the human diet in about the proper proportions. Data collected by the Bureau of Human Nutrition and Home Economics for the years 1944 and 1945 show that dairy products contained 75 per cent of the calcium and 45 per cent of the riboflavin in the total available food supply as well as 24 per cent of the total protein, 17 per cent of the vitamin A, and 17 per cent of the calories.

In addition to the 2,400,000 people on the dairy farms, many other persons and facilities must be employed in moving and processing the milk and milk products before they reach the consumer's table. The exact number of people engaged in these fields is unknown, but over 200,000 people were employed in manufacturing dairy products in 1947. This total does not include the many persons needed to process, bottle, and deliver fluid milk. These marketing services are costly, and on the average the farmer receives only a little over half the amount paid by consumers for dairy products. Since there are differences in the amount and cost of the marketing services for the various dairy products, the farmer's share of the consumer dollar is affected by the way in which the milk is used. For example, the farmer's share of the consumer's dollar spent for butter is nearly 70 cents. In the evaporated-milk industry, however, less than 40 cents out of each dollar spent by consumers goes to the farmers as payment for milk. Price fluctuations also influence the farmer's share of the consumer dollar since the cost of marketing or marketing margins are relatively inflexible. When prices of dairy products rise, marketing costs do not necessarily rise proportionately so fast, and a higher percentage of the consumer payments are passed on to the farmer. Conversely, when agricultural prices fall, marketing costs tend to remain relatively fixed, and the farmer's share of the consumer dollar drops.

Milk Production and Utilization. The total amount of milk produced annually in the United States is about 120,000,000,000 pounds. If this amount of milk produced in a single year were placed in tank cars each of which would hold 56,000 pounds of milk, it would require 42,857 trains of 50 cars each. A single day's production would fill 117 such trains. This would be enough milk to supply each man, woman, and child in the United States with about 1 quart of milk per day, if all the milk produced were used for human consumption. Some of the milk is kept on the farm for such uses as livestock feed, farm-made butter, and for use on the table of the farm household. A small amount is retailed by farmers as milk and cream, but over 75 per cent of the total milk production was delivered to dairy plants in the form of milk or cream in 1948. Nearly three-fourths of the milk fat delivered to plants was in the form of milk, and the remainder was made up of farm-separated cream. Since 1930, a very remarkable shift has taken place in the form in which milk fat is delivered by farmers to dairy plants. During the Second World War large quantities of non-fat dry-milk solids were needed as human food. Consequently, prices paid for skim milk were raised, and the farmers in many areas of the country shifted from cream deliveries to milk. The shift was greatest in the West North Central States, but large quantities of farm-separated

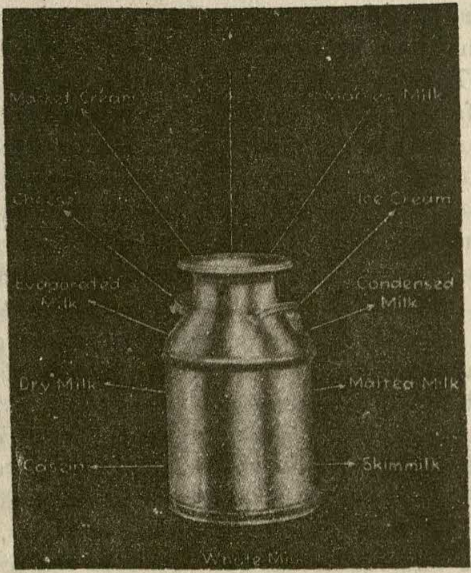

FIG. 4. There are about 120,000,000,000 pounds of milk produced in the United States annually. This milk is sold in the form of market milk, cream, and several manufactured products.

PROPORTION OF TOTAL MILK FAT DELIVERED TO DAIRY PLANTS IN FORM OF WHOLE MILK IN THE UNITED STATES FROM 1936 TO 1948[1]

Area	1936–1940	1942	1944	1946	1948
North Atlantic	96.5	97.9	98.3	98.8	98.8
E. North Central	69.7	85.1	87.6	90.9	91.4
W. North Central	14.7	22.1	30.3	40.2	39.8
South Atlantic	77.2	84.0	86.6	88.6	89.9
South Central	44.3	55.7	62.0	71.1	73.4
West	59.5	70.0	79.6	85.6	85.7
Total U.S.	55.8	65.4	70.9	76.8	77.9

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[1] Adapted from "Farm Production, Disposition and Income," *Milk*, U.S. Department of Agriculture, BAE Annual.

cream are still delivered to dairy plants in this area. The skim milk is retained on farms as feed for poultry, hogs, and other livestock.

The vast quantities of milk and cream delivered to dairy plants are used in various branches of the industry commonly termed the "market-milk," "cheese," "butter," "ice-cream," or "concentrated-milk" industries. The by-products, including skim milk, buttermilk, and whey, are also processed into a wide range of products both for human and animal feed. The principal uses for the milk supply in 1948 are shown in Fig. 5.

Market Milk. Over 35 per cent of the total milk produced is utilized as fluid milk or cream. In a later chapter, further details are given regarding the means by which great cities are now supplied with safe, wholesome milk. Pasteurization, mechanical refrigeration, and the use of methods based upon an understanding of the sanitary and scientific questions involved have made this possible.

Butter. About 20 per cent of the milk is used for making butter. During the Second World War, butter declined in relative importance because under the existing price controls and rationing the demand for other dairy products drew the available milk supplies away from butter. Some recovery has been made, but as late as 1950 butter production and consumption were well below prewar levels.

In 1949, 1,408,605,000 pounds of creamery butter were manufactured in the United States. Another 300,000,000 pounds of butter were made on farms in the same year. During recent years the amount of farm-made butter has declined rather rapidly. The principal butter-producing area of the United States is the West North Central section including Minnesota, Iowa, Missouri, North and South Dakota, Nebraska, and Kansas. Next in importance is the East North Central section which includes the states of Ohio, Indiana, Illinois, Michigan, and Wisconsin. The three states which lead in the production of butter are Minnesota, Iowa, and Wisconsin.

Cheese. The amount of milk used for cheese is relatively small in comparison with that used for household purposes or for butter making. The percentage utilized by the cheese industry in 1948 was about 9.3 per cent of the total milk produced. Many varieties of cheese are made in the United States, chiefly by following the processes of manufacture originated in some locality in Europe. Among those made in the United States and placed on the market either under the European name or with the original name preceded by the word "American" are Cheddar, Swiss, Münster, Limburger, Roquefort, Camembert, Primost, and a few Italian varieties. The practice of marketing process or pasteurized cheese under trade names has developed widely in the United States. The production of all types of whole-milk cheese other than Cottage cheese in 1948 was 1,094,425,000 pounds, about 85 per cent of which was Cheddar. The leading cheese-producing state is Wisconsin where nearly 50 per cent of the total is manufactured. Other states of importance in the manufacture of cheese are Missouri, Illinois, Minnesota, and New York.

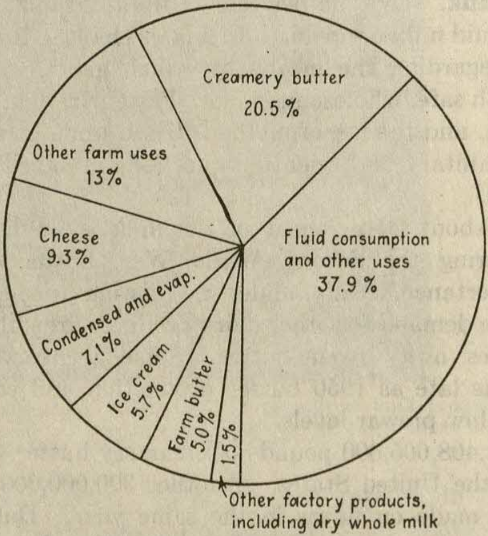


FIG. 5. Percentage utilization of milk supply in the United States, 1948.

The average cheese factory in the United States is small as compared with those factories in which market milk is processed or in which butter, ice cream, or concentrated milk is made. In the state of Wisconsin, for example, there are nearly 1,400 small cheese factories. There is a growing tendency, however, for the establishment of larger factories or units capable of making cheese in larger volume. In many of the newer producing areas, such as Minnesota, cheese is made in larger modern plants. In the older producing areas, such as Wisconsin, there has been a gradual growth in the average size of cheese plants. Many of the smaller cheese factories have been closed, and several large plants have been built. In these plants many of the jobs formerly done by hand are now performed by machines.

Concentrated Milk. Gail Borden was awarded a patent on a process for producing condensed milk in 1856. He established the first condensed-milk factory in Wolcottville, Litchfield County, Conn., that same year. Thus, the foundation was laid for what is now often termed the "concentrated-milk" industry.

Concentrated milks are prepared for market in various forms. In one case only a portion of the water is removed from the fluid milk, and the resulting product is still liquid in nature. The evaporated milk commonly found on the grocery shelf today represents a product of this type. The other types of condensed milk are described in a subsequent chapter. The production of condensed or evaporated milk (whole or skim) in the United States was over 4,600,000,000 pounds in 1948.

A dry product is prepared by removing nearly all the water from the fluid milk. This dried milk has become an important factor in the preservation of the solid constituents of large quantities of whole milk, skim milk, buttermilk, and whey for human food or feed for animals. Other products such as cream, malted milk, casein, and ice-cream mix are also dried, but in much smaller quantities. Total dry-milk production in 1948 was over 1,000,000,000 pounds. Dry skim milk (non-fat dry-milk solids) represented over 65 per cent of the total production. Over 170,000,000 pounds of dry whole milk were also produced in 1948. Wisconsin, Minnesota, New York, California, Ohio, Illinois, Michigan, and Missouri are the principal states in which concentrated milks are produced. Almost one-fourth of the condensed and evaporated milk produced in the United States comes from Wisconsin plants.

In contrast to the small cheese factories in the United States, plants designed to handle concentrated-milk products are very large. It is not unusual for plants making evaporated milk to handle 500,000 pounds of milk daily, while some are known to process more than 1,500,000 pounds each day. Large central plants for drying whole milk, skim milk, buttermilk, and whey may receive and process well over 1,000,000 pounds of fluid milk during one day's operations.

Ice Cream. The ice-cream industry produces more than 500,000,000 gallons of all types of frozen dairy products annually. The chief products of the ice-cream factory are ice cream, sherbet, and ices. Frozen products in which cream is the chief constituent have been made in the household for nearly 100 years, but the manufacture of ice cream in the factory has been a development of the past half century. These factories are found principally in the larger cities and towns scattered throughout the United States. Ice cream must be held frozen until consumed and is not commonly shipped as great distances as other dairy products. Relatively little attention is given to the local supply of milk or cream in locating an ice-cream plant. The demand or possible outlet for the finished product is a more important factor in determining where to locate plants of this type since transportation of ice cream is very costly. The raw products required for ice cream, however, may come from distant localities where there is a heavy production of milk and cream.

It is a well-established fact that the ice-cream industry is greatly affected by economic conditions. The demand for frozen desserts increases relatively more than the demand for other dairy products during periods of prosperity. During depressions, the converse is true, and the ice-cream industry is one of the first to be affected by declines in consumer purchasing power. Not only does the industry quickly reflect economic conditions, but it is also seasonal in nature. The demand for ice cream during the summer months greatly exceeds the requirements during the winter.

By-products. By-products from butter and cheese making are also processed by the dairy industry. In addition to large quantities of skim milk and buttermilk used in fluid form, over 13,000,000,000 pounds were used in the manufacture of various products in 1948. About 70 per cent of this total went into nonfat dry-milk solids, dried buttermilk, and casein, but sizable quantities of condensed and evaporated skim milk as well as Cottage, Pot, and Baker's cheese were also produced. Whey is the by-product which is left after making the various types of cheeses. More than 125,000,000 pounds of whey powder were produced in the United States in 1948. Over half the total production of whey originated at drying plants located in the state of Wisconsin. Some of the dry whey is utilized for human food and in the preparation of milk sugar, although most of the dry product is used for animal feed.

Demand for Milk and Milk Products. One of the important factors affecting the total amount of milk produced and the way in which this milk is utilized is the demand for the various products. If more milk is produced than consumers are willing to buy at prevailing prices, prices of the various products will fall. As the prices of milk fall, milk production becomes less profitable and less milk is produced. Similarly, if milk prices are high enough so that dairying is more profitable than other farm enterprises, farmers will shift to dairying or expand production of existing herds. This will greatly expand the supply of milk and tend to lower the prices from the profitable levels which previously existed. Within the dairy industry the laws of supply and demand help to allocate the total production among the various uses. If the demand and price relationships in one branch of the industry are such that this use appears more profitable than other uses, milk supplies will be diverted to this product. As more and more of the product is made, the price and profitability will fall, and the diversion of milk supplies will be halted.

The demand for milk is derived from the demands for all dairy products such as market milk, butter, cheese, and ice cream. The demand for the various products depends upon many things, but two of the most important are ability to buy and habits of consumption. The ability to buy depends upon income. Low-income groups tend to spend a greater share of their incomes for dairy products, but their total expenditures for dairy products per family are less than comparable expenditures in the higher income brackets. As incomes increase or decrease, people usually spend more or less for dairy products. Such changes in consumer expenditures for dairy products do not result in proportional changes in consumption of the various products. For example, when incomes change there is a tendency for greater relative increases or decreases in the consumption of items such as ice cream as compared with fluid milk. Often the consumption of one or more dairy products may be increasing at the same time that the per capita sales of another product are being reduced. Prices of the dairy products, also, tend to rise and fall with changes in income. The fact that consumers are spending more or less on dairy products does not necessarily mean that they are consuming more or less dairy products. As a result of these factors, the total per capita consumption of milk has been subject to relatively little change from year to year except during the war years, when diversions to overseas use caused abnormal reductions in domestic consumption. Habits of consumption, however, have changed greatly among the different dairy products.

Per Capita Consumption of Dairy Products. The per capita consumption of fluid milk and cream at the present time is about 45 gallons per year. Consumption per capita has declined since 1945 but is still well above prewar levels. Prior to the Second World War, the average consumption of butter per capita was about 17.5 pounds. During the war, milk supplies were needed for other purposes, and butter consumption fell rather sharply to about 10 pounds per capita. In the postwar years, a slight recovery has taken place, but butter consumption remains well below prewar levels. Cheese consumption was 2.1 pounds per capita in 1889. By 1940 it had increased to 6.0 pounds. During the war years the consumption dropped off slightly, but by 1948 nearly 7 pounds were consumed per capita in the United States. The use of cheese in the United States is far below that of European countries, where the consumption ranges from 8 to more than 20 pounds per capita. Cheese and meat are largely interchangeable in the diet. When the economic conditions are such that meat can be used freely, the cheese consumption is usually limited. This has been the case in the United States, where meat consumption has been high compared with that of Europe.

There has been a gradual increase in the use of concentrated-milk products, especially evaporated milk and dry skim milk (non-fat dry-milk solids). The per capita consumption of evaporated milk was 11.25 pounds in 1930 and had reached 17.4 pounds by 1940. Consumption of evaporated milk dropped off during the war years, but has risen again to well above the 1940 level in the postwar years. The consumption of dry skim milk is relatively small per capita, but it has undergone a very marked increase during the last 30 years. In 1920 there was practically no dry skim milk used for human food. The consumption per capita grew gradually until it was over 2 pounds in 1940. Civilian consumption during the war was somewhat lower, but in the postwar period the consumption per capita has been well over 3 pounds. The per capita consumption of ice

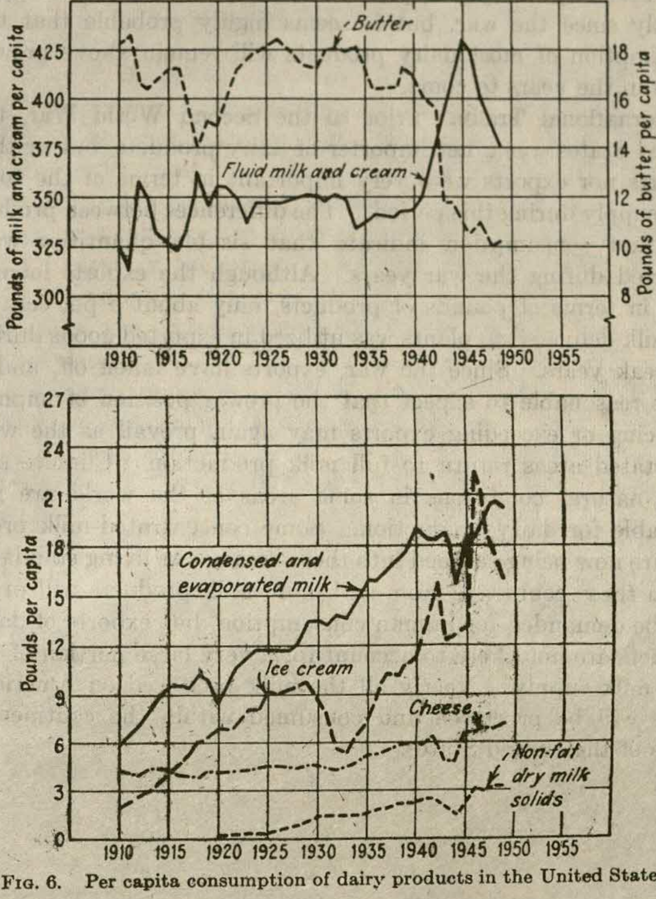


FIG. 6. Per capita consumption of dairy products in the United States.

cream in 1930 was about 9 pounds, but during the depression consumption fell to 5.5 pounds per person. Following the depression, there was a steady increase in ice-cream consumption until the war years of 1942 and 1943 when a slight drop occurred. In 1945 consumption per capita again began to increase and reached a peak in 1946. Changes in consumers' real income have a great effect upon the per capita consumption of ice cream.

Since 1920 the consumption per capita of most dairy products. with the exception of butter, has been moving gradually upward. The war accentuated these upward trends in consumption since incomes and purchasing power were high during this period. The consumption per capita of some products has dropped slightly since the war, but it seems highly probable that the consumption of most dairy products will remain above prewar levels in the years to come.

International Trade. Prior to the Second World War, the United States was a net importer of dairy products, but neither imports nor exports were very important in terms of the total milk supply during this period. The differences between production and consumption indicate that sizable quantities were exported during the war years. Although the exports loomed large in terms of pounds of products, only about 5 per cent of the milk delivered to plants was utilized in exported goods during the peak years. Since the war, exports have fallen off, and it seems reasonable to expect that the prewar position of imports balancing or exceeding exports may again prevail as the war-devastated areas return to full milk production. Climate and other natural conditions in some areas of the world are not favorable for dairy production. Some concentrated-milk products are now being shipped into these areas. As living standards rise in these countries, more and more milk products will probably be demanded for human consumption, but exports of dairy products are not likely to account for a very large portion of the total milk supply. Nearly all the milk produced on American farms will be processed and consumed within the continental limits of the United States.

CHAPTER II

THE CONSTITUENTS OF MILK

Milk as an article of food for mankind antedates the earliest recorded history. Its complex nature and unusual properties have baffled man since the time when he first became interested in the world about him. From the time when the Greeks theorized regarding the nature of milk and its origin to the present, it has been subjected to study by scientific minds of each generation. Most of the exact knowledge of the subject, however, is the product of the past 85 years. Undoubtedly, the future will show the present knowledge of the subject still to be very incomplete.

Milk may be defined as the normal secretion of the mammary glands of mammals. Nature designed milk as a food for the young. Mankind, thousands of years ago, learned the possibilities of milk and milk products as a food not only for the young but for adults. Accordingly, through selection and breeding, man has greatly increased the milk-producing functions of those animals best adapted as a source of milk for man, especially the cow and the goat. Other animals used as a source of milk for human food are the water buffalo, sheep, the camel, and, to a small extent, the mare and the llama. The milk of different species, although containing the same constituents in general, varies in composition and properties in minor ways. Although all the species mentioned are used as a source of milk by certain peoples, the cow supplies such a large proportion of the product used, especially in Europe and America, that little attention need be directed toward the product of other species. The term "milk" always will be understood as referring to the milk of the cow unless other species are mentioned specifically.

General Characteristics of Milk. An intelligent observer, examining milk for the first time, would note the characteristics set forth below. Milk ranges in color from a bluish-white to an almost golden-yellow, depending upon the breed of cattle, the

16765

amount of fat and solids present, and, most of all, upon the nature of the feed consumed by the cow. In large quantities, milk appears entirely opaque, while in thin layers it is somewhat transparent. Milk from which the fat has been removed or that is naturally very low in fat and other solids shows a bluish tint.

Milk has no pronounced taste but is slightly sweet to most persons. Any pronounced taste is abnormal. Freshly drawn milk has a characteristic, but not very pronounced, odor which is quite volatile and which practically disappears when the milk is exposed to the air. Other odors are abnormal and have their origin in sources discussed elsewhere.

If fresh milk is tested with litmus, the so-called "amphoteric reaction" will be found; that is, blue litmus turns red, and red litmus turns blue. When phenolphthalein is used as an indicator, normal fresh milk shows an acid reaction and if titrated with a standard alkali solution the acidity will be found to vary from 0.10 to 0.26 per cent calculated as lactic acid. Fresh milk has a hydrogen-ion concentration of approximately pH 6.5 which indicates that it is really somewhat on the acid side of neutrality.

Milk appears unchanged by heating until a point near the boiling point is reached when a tough film forms on the surface. Prolonged boiling results in a brown shade of color and a change in the taste.

The addition of acids results in the formation of a precipitate which appears as a soft, white, jelly-like mass, known as "curd" with more or less separation of nearly clear fluid or "whey."

If examined under a compound microscope, immense numbers of glistening, spherical bodies of varying sizes will be seen in the milk. If tested in an appropriate manner, these would be found to be fat. When a portion of the fresh milk is allowed to stand undisturbed for a few hours, a layer forms on the surface—the well-known cream. It is due to the gathering of the fat globules in a portion of the milk. If the milk is allowed to remain at ordinary temperatures (60 to 70°F.) (15.6–21.1°C.) for 24 hours or longer, usually it will have a pronounced acid taste and, sooner or later, will coagulate as a soft, jelly-like mass.

Chemical Composition. It is important that the student first become familiar with the chief components of milk, leaving until later a consideration of those which are present in small quantities, even though they may be of importance.

A chemist might describe milk as, essentially, an emulsion of fat in a watery solution of sugar and mineral salts, and with protein in a colloidal suspension. If asked to analyze an average sample of milk and determine the chief constituents, a chemist would report approximately as follows:

		Percentage
Water		87.25
Dry matter		12.75
Fat	3.80	
Protein	3.50	
Sugar	4.80	
Ash	0.65	
Total		100.00

There are certain terms used in connection with the above constituents when referring to them singly and in groups. "Milk fat" or "butter fat" refers to the fat of milk. The protein, sugar, and ash or salts of milk are termed "milk solids-not-fat" or "solids-not-fat." Those in dairy work often refer to this group of solids as the "serum solids" of milk. The dry matter is commonly designated as "total solids."

Water in Milk. In average milk, about 87 in each 100 pounds is water. This water is not different from ordinary water and serves to hold in solution the soluble constituents of the milk. The percentage of water varies from 84.0 to 89.0 per cent although, occasionally, an individual sample of authentic milk may exceed these limits. Any variation in the amount of other constituents is also reflected upon the water percentage. The fluid nature and the high water percentages, as given above, often lead to an erroneous conception of the food value of milk. The facts are that many other articles of food, including radishes, carrots, and pumpkins, contain even more water than milk, while apples and potatoes rank but little above the richer milk samples in this respect. Among cattle feeds, fresh grass and root crops have less dry matter than milk, and some silages but little more.

FAT OF MILK

Milk fat often called "butter fat," is, commercially, the most valuable constituent of milk. It is also of great importance from the standpoint of the food value of the milk. The agreeable flavor of rich milk, and to a large extent of other dairy products, is largely due to the milk fat. If all the milk produced in the United States could be brought together it would contain about 3.8 pounds of fat to the hundredweight. To give 3.8 as the average percentage, however, is misleading, so far as many localities are concerned, because of the preponderance of certain breeds of cattle in some localities. In the South, for example, where the Jersey is widely used, average milk would show a fat percentage of at least 4.5 and possibly even 5.0, while in those localities in the Northern states where Holsteins are generally used, the average percentage would be nearer 3.5. The fat percentage will seldom be less than 2.5 or more than 6.0, although occasionally milk from a single animal will exceed these limits.

The cream separator concentrates the milk fat into a small portion of the milk. The product is known as "cream." Normally, cream for table use contains from 18 to 25 per cent of milk fat. This cream is termed "light," "coffee," "single," or "table cream" on the various markets of America. The minimum fat content of cream is fixed by federal regulation at 18 per cent. This requirement applies only to cream shipped in interstate commerce as is the case with all federal laws relating to food products. The fat content of cream has been fixed in the various states and territories of the United States ranging from 16 to 20 per cent, the majority having established the minimum fat content at 18 per cent. Ordinary whipping cream usually contains from 30 to 40 per cent of milk fat, depending upon federal or state laws and regulations. The federal regulation defines "light" whipping cream as containing not less than 30 per cent of milk fat but less than 36 per cent. "Heavy" whipping cream must contain not less than 36 per cent milk fat according to federal regulation. The laws defining whipping cream vary in states and municipalities, although a few have adopted the federal standards. Large volumes of cream are shipped from the Middle Western states to markets in short supply. This cream is generally separated to contain 50 per cent of milk fat. Cream containing 65 to 80 per cent of milk fat has been termed "plastic" or "extra heavy" cream.

When cream is churned, the milk fat is gathered into a concentrated mass, and, after working, it is known as "butter." Butter is, therefore, a concentrated substance containing from 80 to 85 per cent of milk fat. The milk-fat content of butter is fixed by federal regulation at not less than 80 per cent. This standard has been adopted by all the states and territories of the United States except Wisconsin where butter must contain 82.5 per cent of milk fat. Milk fat in butter may be further concentrated by means of separation to produce "butter oil" or "dry butter" which may contain 98 to 99.5 per cent of milk fat.

Practically all the dairy products, with the exception of those made from skim milk, contain an appreciable amount of milk fat. Cheddar cheese contains from 30 to 40 per cent of this constituent, and its rich, mellow flavor is very largely dependent upon the amount of milk fat present. Ice cream varies in its milk-fat content from 8 to 20 per cent. The quality of this product, also, is closely associated with the milk fat it contains. Evaporated milk and dry whole milk contain an average of about 8 and 26 per cent of milk fat, respectively. Their goodness and pleasing taste are closely linked with the presence of milk fat.

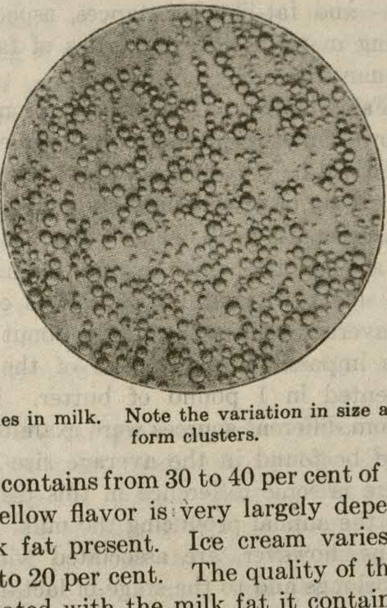


FIG. 7. Fat globules in milk. Note the variation in size and the tendency to form clusters.

The Structure and Nature of the Fat of Milk. Milk fat exists in milk in the form of minute globules in a true emulsion of the oil-in-water type, the fat globules being in the dispersed phase. The fat globules are invisible to the naked eye, but are seen readily under the low power of a microscope.

Early investigators advanced a theory that the fat globules of milk are surrounded by a membrane. No convincing evidence, however, was produced to support this view and, consequently, the membrane theory has been generally discarded. As a result of the newer knowledge in the field of physical chemistry, the view in recent years has been that each globule of fat is surrounded by a very thin film of protein, or the serum of milk, concentrated on the surface and held in place by surface attraction or adsorption. This concentration of the milk proteins around the fat globule is one factor assisting in maintaining the stability of the fat emulsion in milk. More recently, experimental evidence has been presented to indicate that the concentrated layer surrounding the fat globules is composed of certain protein- and fat-like substances, especially lecithin, a substance having many of the properties of fat, and found in milk in small quantities.

Size of the Fat Globules. If a sample of milk is examined under a high-power microscope enormous numbers of fat globules will be seen. It will be observed that they vary widely in size, the largest having six or seven times as great a diameter as the smallest. Measurements will show that the average-sized globules have a diameter which would require about 10,000 placed side by side to extend 1 inch. It is estimated that a single drop of average milk will contain about 100,000,000 fat globules. It is impossible to conceive of the number of fat globules represented in 1 pound of butter. If a number of milk samples from different sources were examined, considerable difference would be found in the average size of the globules. Apparently there is some difference in this respect due to the individuality of the animal producing the milk. The most consistent variations, however, are associated with the breed to which the cow belongs and to the stage of lactation.

Of these, the breed is the most important factor. It is possible, by a microscopic examination, to distinguish the milk from a Holstein or Ayrshire cow from that produced by a Guernsey or Jersey. Among the breeds commonly used in America for dairy purposes, the Jersey and Guernsey breeds produce the largest globules, the Holstein and Ayrshire stand at the other extreme, with other breeds intermediate.

During the first part of the lactation period, the fat globules are relatively large while as the lactation period progresses the globules become smaller. This fact has been offered as one explanation for difficult churning of cream which sometimes occurs under farm conditions, as it is known that milk possessing the smaller fat globules churns more slowly than milk containing large globules.

Practical Importance of the Size of the Fat Globule. The size of the fat globule is of some practical importance in each of the following operations:

1. Separation of milk.
2. Churning of cream.
3. Shipping of milk or cream.
4. Cheese making.

Before the days of the centrifugal cream separator when gravity creaming of milk was practiced, the size of the fat globule was a matter of considerable importance because it was a factor in the loss of fat in the skim milk. Some difference can readily be observed in this respect by comparing the time required for the appearance of cream in the top of an ordinary milk bottle, using the product from different breeds. Since the introduction of the cream separator, the size of the fat globules has ceased to be a factor of importance in cream separation because the centrifugal force is so many times greater than the force of gravity that a difference in the size of the fat globules is of little importance, although careful tests usually will show a very small difference.

The size of the fat globules bears a definite, although not particularly important, relationship to the churning of cream. Cream with large fat globules churns with less agitation than that in which the smaller globules predominate. In this connection it is well to recall the fact that the surface of spheres varies according to the square, and the volume according to the cube, of their diameters. A globule having twice the diameter of another has four times the surface and eight times the volume. The surface of the larger globule, as a result, is much less in proportion to the volume, and the surface tension which keeps the fat in the form of an emulsion is likewise easier to overcome by the agitation of churning.

The size of the fat globule is of some importance in connection with the handling and shipping of milk. Milk having large globules churns more readily, and after being transported some distance and passed through various apparatus may show some evidence of partial churning in the form of butter granules on the surface. The trouble is usually prevented by filling the can or other container completely to the lid, thus allowing no chance for agitation. In cheese making, the size of the fat globules is a matter worthy of consideration. When the milk contains large fat globules the cream comes to the surface of the milk in the cheese vat more quickly, and before the coagulation of the milk by the rennet has had time to check the movement of the fat and lock it within the coagulated casein. As a result, the loss of milk fat in the whey is somewhat larger. It has also been claimed that smaller fat globules are more readily digested than the larger, but little, if any, evidence is available to prove the correctness of such a statement.

Composition of Milk Fat. Milk fat is not a single chemical compound but a variable mixture of several different glycerides. Each glyceride is the result of the union of glycerol and one or more organic acids. The organic acids contained in milk fat and fats from other sources other than milk fat are commonly termed "fatty acids." The common animal fats are relatively simple as compared with milk fat. Beef fat consists of the glycerides of palmitic, stearic, and oleic acids. Mutton tallow consists principally of the glyceride of stearic acid, while lard is primarily made up of the glyceride of oleic acid. Milk fat probably contains a larger number of the fatty acids than any other fat found in nature. It is, therefore, one of the most complex natural fats known to nature. It has been shown definitely that milk fat contains butyric, caproic, caprylic, capric, lauric, myristic, palmitic, stearic, and oleic acids. At least seven others have been reported by various workers, but some doubt prevails as to whether all these are actually present in normal milk fat.

The complexity of milk fat may be comprehended more readily when the chemical formulae for glycerol and the fatty acids are known. Glycerol is written $C_3H_5(OH)_3$ and butyric acid, for example, is written, C_3H_7COOH. Milk fat is a triglyceride. This is true of most animal fats. It means that 1 molecule of glycerol is combined with 3 molecules of the fatty acid. When it is realized that glycerol combines with one or more of the fatty acids to form the glyceride of the fatty acid, it may be seen that the chemical structure of milk fat may be exceedingly complex.

The composition of milk fat, as reported by the workers of the Massachusetts Experiment Station, is indicated in the following statement:

Fatty Acids in Twenty-one Samples of Butter Fat from Massachusetts Cows Fed Normal Rations

Fatty acids	Chemical formula	Average, percentage	Range, percentage
Soluble acids:			
Butyric (*a*)[1] (by difference)	C_3H_7COOH	2.932	2.41 to 4.230
Caproic (*a*)[1]	$C_5H_{11}COOH$	1.898	1.290 to 2.400
Caprylic (*a*)[1]	$C_7H_{15}COOH$	0.786	0.527 to 1.041
Capric (*a*)[1]	$C_9H_{19}COOH$	1.570	1.187 to 2.008
Total		7.186	6.470 to 8.601
Insoluble acids:			
Lauric	$C_{11}H_{23}COOH$	5.849	4.533 to 7.687
Myristic	$C_{13}H_{27}COOH$	19.784	15.554 to 22.618
Palmitic	$C_{15}H_{31}COOH$	15.167	5.782 to 22.863
Stearic	$C_{17}H_{35}COOH$	14.907	7.803 to 20.370
Oleic	$C_{17}H_{33}COOH$	31.895	25.273 to 40.313
Total		87.602	86.145 to 88.471
Total fatty acids		94.788	94.746 to 94.980

[1] *a* = 20 samples analyzed.

The average analyses given by these workers conform in most instances with the reports of earlier investigators. The work of recent years has differed in that it has brought out the fact that milk fat can be expected to vary not only in the proportion of fatty acids but in those present

The composition of milk fat as reported by Hilditch and Jones of the University of Liverpool will be of interest in this connection. These workers report the presence of the nine fatty acids generally recognized in milk fat and, in addition, arachidic and linoleic acids.

Volatile and Non-volatile Groups. It has been the common practice to divide the fatty acids of milk into two general groups, the volatile and the non-volatile. While these terms are not strictly accurate as applied to the fatty acids of milk fat, this grouping serves a useful purpose in indicating general properties. The volatile acids include butyric, caproic, caprylic, capric, lauric, and small quantities of others. Butyric, caprylic, and capric of this group are classed as soluble fatty acids. The non-volatile are myristic, palmitic, oleic, stearic, and small quantities of a few others. This group of fatty acids including lauric of the volatile group are classed as insoluble fatty acids.

Composition of New Zealand Butter, Market Samples
As reported by Hilditch and Jones of the University of Liverpool

Fatty acid	Sample		
	A per cent	*B* per cent	*C* per cent
Butyric	3.4	3.1	3.2
Caproic	1.8	1.9	1.7
Caprylic	0.9	0.8	0.8
Capric	1.9	2.0	2.3
Lauric	3.1	3.9	4.3
Myristic	9.7	10.6	10.8
Palmitic	27.6	28.1	28.4
Stearic	12.2	8.5	9.4
Arachidic	0.7	1.0	0.5
Oleic	34.3	36.4	33.1
Linoleic	4.4	3.7	5.4

The glycerides of the volatile group, butyrin, caprin, etc., make up about 17 per cent of the total in milk fat. It is this group of fats to which the characteristic flavors of butter and cream are generally attributed. Butyric acid is the most important acid found in this group. Butyric acid contributes to butter its characteristic taste and, on being liberated, is largely responsible for the rancid flavor which sometimes occurs in dairy products. Of the volatile fatty acids, butyric is the most variable. A slight decrease in the butyrin content of milk fat takes place as the lactation period progresses. Corn silage is also known to produce an increase in the butyrin content of milk fat, while cottonseed meal has been shown to cause a decrease in the butyrin content.

The glycerides of the fatty acids found in the non-volatile group, myristin, palmitin, etc., constitute 82.7 per cent of milk fat. This group of fatty acids is particularly important because of their relation to the hardness or softness of milk fat and their ultimate relation to the texture of butter. The practical creamery man witnesses the influence of these fatty acids because of their effect on the temperature required for churning cream at various seasons of the year. In the spring months, there is a predominance of the fats possessing a low melting point which results in a soft butter and necessitates the churning of the cream at relatively lower temperature. During the winter months, when fewer of the fats of a low melting point are present, a higher churning temperature is therefore essential.

Oleic acid is the most variable of this group and, likewise, possesses the lowest melting point. It is, therefore, the chief acid influencing the hardness or softness of milk fat. It is known that the oleic acid content of milk fat increases when cows are permitted to graze on green grass, when fed linseed meal, cottonseed meal, and as the period of lactation progresses.

Though it is possible to classify the fatty acids into volatile and non-volatile groups and into soluble and non-soluble groups, neither of these classifications can be applied to the fats formed in the union of the fatty acids with glycerol. The fats are neither volatile nor soluble in water. When decomposed by bacteria or by chemical means, however, the fatty acids may be liberated, and their properties revealed. Rancidity of butter, for example, is said to be due to the breaking down of a triglyceride containing butyric acid and the liberation of butyric acid, which yields a rancid odor and taste.

Properties of Milk Fat. Since milk fat is a mixture of fats, it cannot have a true melting point. By placing a disc of fat in alcohol and water and raising the temperature of the solution it will be observed that normal fat will melt and form a sphere at about 91.4°F. (33°C.). Variations can be expected from 84 to 96.8°F. (29 to 36°C.), depending upon the proportion of hard and soft fats present. Each fatty acid contained in milk fat possesses a different melting point, as will be noted in the following table, which presents, in addition to the melting point, the boiling point and specific gravity of each of the fatty acids known to be contained in milk fat.

PROPERTIES OF THE FATTY ACIDS[1,2]

Acid	Melting point		Boiling point		Specific gravity
	Degrees Fahrenheit	Degrees Centigrade	Degrees Fahrenheit	Degrees Centigrade	
Butyric....	17.8	−7.9	326.3	163.5 at 760 millimeters	0.959 at 20/4°C.
Caproic....	30.8–28.4[2]	−1.5–2[2]	395.6	202 at 760 millimeters	0.929 at 20/4°C.
Caprylic....	60.8	16	459.5	237.5 at 760 millimeters	0.910 at 20/4°C.
Capric.....	87.8	31	515.1	268.4 at 760 millimeters	0.895 at 30°C.
Lauric.....	118.4	48	437.0	225 at 100 millimeters	0.883 at 20/4°C.
Myristic....	136.4	58	482.9	250.5 at 100 millimeters	0.858 at 60/4°C.
Palmitic....	147.2	64	419.0	215 at 15 millimeters	0.853 at 62/4°C.
Stearic.....	156.7	69.3	721.4	383 at 760 millimeters	0.847 at 69.3°C.
Oleic.......	57.2	14	546.8	286 at 100 millimeters	0.895 at 17.7/4°C.

[1] International Critical Tables, 1926.

[2] "Handbook of Chemistry and Physics," 3d ed.

Melting Point of Milk Fat. The melting points of the fatty acids closely correlate with the melting points of the fats; however, butyrin has a melting point of about −94°F. (−70°C.) and olein 41°F. (5°C.). The other fats of importance are as follows: myristin 129.2°F. (54°C.), palmitin 141.8°F. (61°C.), and stearin 149°F. (65°C.). Thus, it is seen that of the fats in milk fat the principal soft fats are butyrin and olein, and the principal hard fats are myristin, palmitin, and stearin. The melting point of milk fat is influenced by its composition. An increase in the olein content of milk fat will result, therefore, in a lower melting point; likewise, will an increase in the butyrin content. Should olein be decreased and palmitin or stearin be increased, the melting point would rise. Likewise, butter would vary in its firmness according to the proportion of the hard and soft fats present.

Closely associated with the melting point of milk fat is the solidifying point or the temperature at which it appears solid. The majority of the glycerides of the fatty acids of milk fat solidify at 50 to 53.6°F. (10–12°C.). The specific gravity of milk fat is generally considered to be about 0.9 at 140°F. (60°C.)

Other Properties of Milk Fat. Milk fat is insoluble in water but it will absorb about 0.2 per cent of it. It is soluble in ether, carbon disulfide, nitrobenzene, and in acetone. It is only slightly soluble in ethyl and amyl alcohol but a larger portion is soluble in hot amyl alcohol and hot glycerol.

In addition to the above properties, milk fat will absorb volatile odors very readily. Because of this property butter, milk, and cream should not be stored near the source of volatile odors which might contribute an off-flavor to these products. This fact is rather commonly known to practical men handling butter in creameries, warehouses, in transit, and in retail stores. The housewife who places butter in an icebox with fish or any food from which an odor is given off, may expect butter to absorb these odors very readily.

Factors Influencing the Composition of Milk Fat. It has been stated that milk fat is a variable mixture of several different glycerides and that each glyceride is the result of the union of glycerol and one or more fatty acids. Attention has also been directed to the fact that the composition of milk fat varies. The principal fats which are known to vary are butyrin, olein, palmitin, and stearin. Variations in these fats are responsible for variations in the melting point of milk fat. The principal factors which have been demonstrated as being responsible for variations in the different fats of milk fat are breed of animal, stage of lactation, feed, and plane of nutrition.

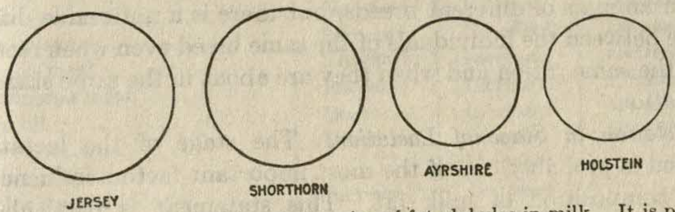


FIG. 8. Relation of breed to relative size of fat globules in milk. It is possible to distinguish typical Jersey or Guernsey milk from Holstein or Ayrshire milk by microscopic examination.

Relation of Breed. It has been demonstrated, experimentally, that the milk fat of the milk of Jerseys contains fat higher in the volatile acids than the milk fat of the milk of Holsteins, Ayrshires, or Shorthorns. The principal variation probably occurs in the butyrin content of the fat. The oleic acid content of fat produced by Holsteins and Shorthorns is noticeably higher than that from the Jersey, while in fat from the Ayrshire it is intermediate between these. The melting point of the fat produced by Holsteins and Ayrshires is, therefore, lower than that of Jerseys. Butter produced from the Jersey cream, under normal conditions, may be expected to be firmer than that produced from the cream from Holsteins or Ayrshires. In those localities in which Holsteins and Ayrshires predominate, the creameries use a relatively lower temperature in the churning of cream than in localities in which the Jersey predominates. There is every reason to believe that the fat produced by the Guernsey is very similar to that of the Jersey. Statements made in reference to one would doubtless apply to the other. The influence of the factors of feed and lactation, and feed in particular, however, must be considered in certain localities as will be pointed out.

Not only is there a difference in the composition of the fat from animals of different breeds, but there is a noticeable difference between the individuals of the same breed even when receiving the same ration and when they are about in the same stage of lactation.

Relation to Stage of Lactation. The stage of the lactation period is probably one of the most important factors influencing the composition of milk fat. This statement is particularly true in reference to the influence of the stage of lactation on the volatile acids, principally butyric, of milk fat, which gradually decline from the beginning to the end of the lactation period. The oleic acid content is somewhat irregular at the beginning of the lactation period, but, after this period there is a slight but steady increase. The melting points remains almost constant after the first few weeks of the lactation period. Near the end of the lactation period it rises.

Relation to Feed. One of the most interesting factors influencing the composition of milk fat is that of feed. Certainly its influence is more far-reaching than any of the factors mentioned. The influence of a few feeds as designated by various workers is indicated in the table as shown on page 35.

As a general rule, feeds which cause an increase in the olein content of milk fat produce a soft fat of a low melting point. Cottonseed meal, however, is an exception. In the case of cottonseed meal, the increase in olein is counteracted by the decrease in butyrin which has a very much lower melting point than olein. It has been demonstrated that by feeding corn silage, which tends to increase the butyrin content of milk fat, the influence of cottonseed meal on the melting point of butter can be overcome. The feeds which result in a relatively higher olein content are those feeds rich in vegetable oils, such as linseed meal, soybean meal, and gluten feeds which are rich in fat. In addition, grass pasture brings about an increase in the olein content of milk fat. Feeds low in vegetable oils, and rich in carbohydrates, as a general rule, produce a milk fat of a relatively lower olein content and, consequently, a firmer fat.

Feed	Effect on butyrin	Effect on olein	Effect on melting point
Grass (pasture)	No effect	Increase	Decrease
Corn silage	Increase	No effect	Decrease
Linseed meal	No effect	Increase	Decrease
Cottonseed meal	Decrease	Increase	Increase
Corn oil	Decrease	Increase	No effect
Velvet beans	Decrease	Increase	Increase
Malt sprouts	....	Decrease	
Buckwheat middlings	Increase	Decrease	
Wheat gluten	Increase	Decrease	
Oats	....	Decrease	
Molasses	Increase	....	Decrease
Beets	Increase	Decrease	

It must not be overlooked, however, that if a feed lowers the olein content and produces at the same time an increase in butyrin, the melting point of the milk fat may be affected in one or more ways. It is possible that it would be increased if the proportion of olein and butyrin was such as to permit this to occur. On the other hand, it may be decreased or there may be no influence whatsoever on the melting point of the milk fat or the firmness of the butter. In many instances it is not possible to state definitely the influence of a particular feed on the melting point of milk fat, because no work of this nature has been done on that particular feed.

Relation to Plane of Nutrition. In addition to the influence of feeds on the composition of milk fat, Eckles and Palmer have demonstrated that the plane of nutrition may be a factor, particularly in cases where animals are underfed. They point out that all types of underfeeding have marked effects on the physical and chemical constants of milk fat which are characterized by a decline in the volatile acids and an increase in the olein content of the milk fat produced. The melting point of milk fat as a result of underfeeding may increase, remain stationary, or decrease, depending on the relation of volatile acids, principally butyric, to the oleic acid content.

PROTEINS OF MILK

Proteins are among the most complex of organic substances. They contain carbon, hydrogen, oxygen, nitrogen, sulfur, and sometimes phosphorus. They are characterized chiefly by the fact that they contain nitrogen. Protein is an indispensable part of the food of animals as it is the chief constituent of the protoplasm which forms the vital part of every living cell. Familiar examples of protein are the white of an egg and the curd of milk. Lean meat is chiefly protein with considerable water and some fat.

As would be expected from the purposes of milk in nature, it contains considerable protein. In milk of average composition, that is, with a fat content of about 3.8 per cent, the protein content will be approximately 3 per cent. Nearly all samples of normal milk would come between 2.80 and 4.00 per cent. Greater extremes will be found only rarely. The protein of milk is not a single compound but includes two major proteins and small quantities of others. Of these, casein constitutes about 80 per cent of the total and lactalbumin 18 per cent. A third protein recognized as present in milk is lactoglobulin. It is present in very small amounts, probably about 0.05 to 0.07 per cent. Other nitrogenous substances in milk will be discussed under Minor Constituents. Their presence contributes slightly to the total nitrogen content of milk and thus may be taken into account in making the protein analysis of milk or milk products high in protein.

The proteins of milk, principally casein, are among the chief constituents of the various types of cheese. Cheddar cheese contains approximately 33 per cent of protein. The average protein content of a few of the other more or less common cheeses is as follows: domestic Swiss 26.0 to 30.0, Roquefort 21.0, Camembert 19.0, and Brick 21.0 per cent. The soft cheeses contain a greater percentage of moisture than the hard cheeses and contain from 12.0 to 20.0 per cent of protein, depending on the percentage of moisture and milk fat contained in the cheese.

In the manufacture of ice cream, the proteins constitute a large proportion of the milk solids-not-fat in the mixture and doubtless add to the relative smoothness of the texture of the finished product.

Casein of Milk. There is no other protein in nature similar to casein. As it appears in commerce, casein is a yellowish-white granular substance. In its pure state it is snow-white, odorless, and tasteless. It contributes to the whiteness of milk. In milk, it is found in combination with calcium and is often designated as "calcium caseinate." It is a well-established fact that casein exists in milk in the form of small gelatinous particles in suspension. The chemist refers to this state of dispersion as "colloidal." Casein can be removed from milk by filtering through a porcelain filter or through an animal membrane.

Casein may be precipitated from milk by dilute acids, rennin, and alcohol. The casein precipitated with weak acids is free of calcium. The casein precipitated with alcohol is calcium caseinate. When precipitated with rennin, paracasein is formed. It contains more calcium than calcium caseinate. Pure casein is not precipitated by heat, but in fresh milk prolonged heating at high temperatures (212°F. (100°C.)) for 12 or more hours or 248°F. (120°C.) under pressure will cause the precipitation of casein. On boiling fresh milk, a thin layer of finely precipitated casein, together with other milk constituents including fat, forms a thin layer over the surface of the milk. The application of heat to milk that is slightly acid will cause the precipitation of casein. This fact is known to the housewife who has had the experience of having milk curdle when attempting to heat it in the home. She has learned, too, that when combining milk with acid foods, such as tomatoes, care must be exercised or the milk will "curdle."

Casein in Dairy Products. When milk is separated by means of the centrifugal separator, a large proportion of the casein goes with the skim milk. The serum of the cream contains the same proportion as the serum of the original milk. In making cheese with rennet there is formed from calcium caseinate a new product, calcium paracaseinate. Within this clot are entrapped the other constituents of milk, most of which, excepting the fat, are eliminated into the whey. Casein, therefore, is the principal constituent of cheese. The greater portion of the casein contained in the serum of cream passes to the buttermilk on churning. A very small amount is entrapped in the churned butter granules and, if not removed by washing, is incorporated into the butter.

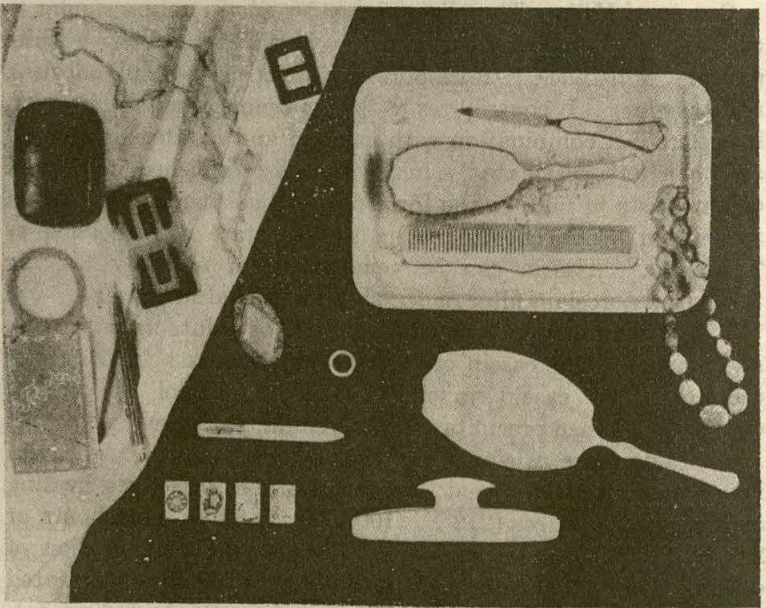


FIG. 9. Articles made from casein plastic. This material is used in the manufacture of a multitude of articles, for example, toilet articles, rims of eyeglasses, fountain-pen barrels, and colored tiles. Casein glue, another product made from this milk constituent, finds a wide industrial use, as in the manufacture of furniture and the sizing of paper.

Commercial Uses of Casein. Casein is prepared in a commercial way by precipitation from skim milk by the use of dilute acids or rennet. Sometimes the milk is allowed to stand until sufficient acid is produced naturally to curdle the milk. After precipitation the whey is partially expelled from the curd by heating and is drained from the curd which then is dried and ground.

Casein finds a wide use in industry. One interesting use is in the manufacture of plastics. Casein plastics are made in rolls, sheets, and tubes. They are very hard, resist the action of water, and take colors readily. They are odorless, noninflammable, and can easily be cut into desired shapes and sizes. Casein plastic is used as a substitute for celluloid, horn, and tortoise shell. From it are made a wide variety of toilet articles such as combs, buttons, and rims for eyeglasses. It also is used extensively for fountain-pen barrels, billiard balls, and for electrical insulations.

One of the most important uses of casein in industry is in the sizing of high-grade paper. Several millions of pounds of casein are used for this purpose annually. It is estimated by the authors that more than 80 per cent of the casein manufactured is used by the paper industry for one purpose or another.

Glue is another important product of this milk constituent. Casein glue is sold in a dry form and is ready to use upon the addition of water. Its strength and resistance to water make it of special value in industry where it finds a wide use. It is commonly used in the manufacture of furniture, door panels, refrigerators, airplanes, and automobile-body frames.

Casein is also an important constituent of cold-water paints, the use of which is increasing rapidly. Paints of this class are used both for exterior and interior work. Casein also is used extensively in the textile industry and in the manufacture of leather of certain grades. Another use is as a spreader in connection with the application of sprays used in horticultural work. The addition of a certain amount of casein causes the spray to spread well over the foliage and to adhere better.

New uses for casein are constantly being found. It is used as a filler or a binder in certain foods. It may serve as the base material for a meat sauce and as a binder in sausage; it may be the principal constituent of certain brands of baby foods. One of the uses of casein is in the preparation of a "casein" fiber. This product, known on the market under various names such as "Aralac," has been used in the hat industry as a substitute for rabbit fur in the manufacture of fur-felt hats. The fiber may be blended with wool, mohair, cotton, or rayon in varying proportions. Possibly it may find a wide use in the textile industry. An improved spun-casein fiber developed by the U.S. Department of Agriculture is combined with wool in the manufacture of an automobile carburetor filter. A stiff bristle is now made from casein for use in paint and other types of brushes. During the Second World War, small quantities of casein were used in the manufacture of synthetic rubber.

Albumin. The term "albumin" is used commonly to designate the protein of milk known chemically as "lactalbumin." The albumin content of milk remains fairly uniform at about 0.5 per cent. It resembles but is not identical with blood albumin. When dried, lactalbumin is a tasteless powder. Like other proteins, albumin has an extremely complex chemical composition. It contains carbon, oxygen, hydrogen, nitrogen, and a small quantity of sulfur. The sulfur content, though small, is about twice that of casein. Albumin contains no phosphorus. Unlike casein, albumin is coagulated by heat, but not by rennet. There is some question as to whether albumin exists in milk in the colloidal state or in true solution. Albumin may be separated from milk by first precipitating the casein by the use of a weak acid, and heating the filtered whey to a temperature of 158°F. (70°C.), or above, for a short period. The turbid appearance of the heated filtrate shows the presence of coagulated albumin. By filtering the heated material the albumin may be recovered on the filter. This method, however, does not result in a complete precipitation of the albumin. Lactalbumin precipitated by the action of heat is insoluble.

Lactalbumin in Dairy Products. The centrifugal separation of cream apparently does not affect the distribution of albumin in the serum. For that reason, the greater proportion of the total albumin of the milk goes into the skim milk when the milk is used for butter manufacture. The serum in the cream also contains the normal percentage, and most of this remains in the buttermilk at the time of churning. A small amount is found in the butter as an ingredient of the buttermilk which remains in the butter when the product is ready for the market.

In cheese making, as the albumin is not coagulated by the rennet, it goes chiefly into the whey. The food value of whey depends upon the albumin, milk sugar, milk ash, and a small amount of fat.

Commercial Uses. Lactalbumin is not used to any extent commercially. Primost cheese, made by boiling off the water from whey, contains albumin as one of the important constituents, the others being lactose, fat, and milk ash.

Other Proteins. In addition to casein and lactalbumin, milk is frequently credited with containing traces of other proteins, namely, lactoglobulin, fibrin, and alcohol-soluble proteins. Lactoglobulin was first isolated from milk by Sibelin and Emmerling, who worked independently. The occurrence of globulin as an independent protein has been questioned by chemists, though its properties are freely discussed. Milk does not contain more than 0.1 per cent of lactoglobulin. Only a trace of fibrin occurs in milk, and under some conditions it is totally absent. Evidence indicates that milk contains an alcohol-soluble protein, the characteristics of which differ from the alcohol-soluble proteins of cereals in which these proteins usually occur.

LACTOSE

Milk sugar, commonly designated by the chemist as "lactose," is found only in milk. It is a reducing disaccharide which upon hydrolysis yields 1 molecule of galactose and 1 molecule of glucose. It has the same molecular formula, $C_{12}H_{22}O_{11}$, as ordinary cane sugar or sucrose. It differs from sucrose, however, in molecular configuration, relative sweetness, solubility, and chemical reactivity. Sucrose is about six times as sweet as lactose. Lactose is in true solution in the milk serum. Its solubility, however, is one-third that of sucrose at 212°F. (100°C.) and one-fourteenth at 32°F. (0°C.). Prolonged heating of aqueous solutions of lactose at temperatures from 212 to 226°F. (100–130°C.) results in a decomposition which is indicated by a light-brown or "caramel" color. In heat-treated milk, in the presence of proteins and certain mineral salts, brown color development occurs quite readily and gives rise to the browning of sterilized milk and of certain condensed- and dried-milk products during storage. The greater chemical reactivity of lactose, as compared with sucrose, is due to the presence of a potentially free aldehyde group in the glucose portion of the molecule.

Chemically speaking, lactose is known to occur in two forms, the alpha and the more soluble beta, both of which may occur as either the hydrate or anhydride. Gillis has formulated the equilibrium relations which exist in lactose solution as follows:

$$\text{Alpha-anhydride } (+\ H_2O) \leftrightarrows \text{alpha-hydrate.}$$
$$\text{Beta-anhydride } (+\ H_2O) \leftrightarrows \text{beta-hydrate.}$$

Milk contains on the average about 4.8 per cent of lactose. Nearly 90 per cent of all samples will show a variation not to exceed 0.20 from the average figure. Some variation occurs with individuals within the breed. The breed itself is a small factor. Milk from the Jersey breed averages about 5 per cent of milk sugar compared with 4.6 per cent for that from the Holstein.

Action of Bacteria on Lactose. Lactose has an important relation to the manufacture of the milk products, due to the fact that it is easily decomposed by bacteria. The lactic acid formed in milk, which gives to milk its characteristic sour taste, is the result of bacterial action on milk sugar.

$$C_{12}H_{22}O_{11} + H_2O(+\text{ bacteria}) = 4C_3H_6O_3 \text{ (lactic acid).}$$

The chemical reaction, however, which takes place when lactic acid is produced from milk sugar by bacteria cannot be expressed quite as simply as above, nor is the amount produced necessarily equal to that indicated. Many other products may result from bacterial action, the nature and amount depending upon a variety of factors. It has been found that 1 gram of lactose may form on decomposition by bacteria 0.8 gram of lactic acid. In the ordinary souring of milk, the fermentation continues until an acid percentage of 0.8 to 1.0 is present at which point the acid itself inhibits further growth of the organisms which produced it. As a rule, not over 10 to 30 per cent of the sugar has been used in the normal souring of milk. If an alkali is added to sour milk to reduce some of the acidity, the acid-forming bacteria that are present again will become active and develop acid to the maximum amount which the particular species can tolerate. As pointed out elsewhere, the acid fermentation is a factor of tremendous importance in both butter and cheese making. In fact, the present processes of manufacturing these products, based upon the experiences of generations, assume that the acid fermentation will occur. The typical butter flavor is undoubtedly due, in part, to products of fermentation in which the sugar takes a part. The same is true for at least the most widely used cheeses. One of the most important parts played by the acid formed by fermentation from the sugar is the checking of the growth of undesirable organisms. If it were not for this action, dairy products would rapidly undergo decomposition that would render them unfit for food.

Lactose in Dairy Manufactures. When milk is used for butter making, the lactose goes chiefly into the skim milk. The serum of the cream contains the same proportion as the serum of the original milk. In the fermentation preceding churning, some of the lactose will be converted into acids although at least 80 per cent will still be in the buttermilk. A very small amount will be carried into the butter dissolved in the water of the butter. This small amount may be entirely converted into acid within a few days. When milk is used for cheese making, most of the lactose follows the whey. The portion which goes into the cheese is fermented largely in the course of a few days. The milk sugar of commerce is prepared from whey, a by-product of cheese manufacture.

As previously mentioned, there are two forms of lactose, alpha and beta. The proportion of these two forms of lactose as they may exist in solution is effected by temperature. In concentrated solutions, the less-soluble alpha-lactose may crystallize out as the hydrate but the proportion of alpha- and beta-lactose remaining in solution assumes an equilibrium. At 32°F. (0°C.) it has been shown that the ratio of beta- to alpha-lactose is 1.65 to 1.0. If the temperature is raised to 212°F. (100°C.) the ratio of beta- to alpha-lactose becomes 1.33 to 1.0. Thus it is possible to shift from alpha- to beta- or from beta- to alpha-lactose by the fluctuation of the temperature of the solution. These facts are important in the manufacture of ice cream, and condensed and dry milk. Each of these products contains a relatively high proportion of lactose. A defect which is commonly termed "sandiness" may appear in ice cream. When a "sandy" ice cream is consumed, it gives one the impression of biting upon sand or ground glass. It is due to the crystallization of alpha-lactose. The defect in ice cream is controlled by limiting the amount of lactose present in the ice-cream mix and by careful control of the storage temperature after the ice cream is frozen and hardened. In the manufacture of sweetened condensed milk a similar defect may occur when large crystals of alpha-lactose form in the product. A control of the defect in sweetened condensed milk is exercised by prompt cooling to 86°F. (30°C.), seeding with very fine crystals of alpha-lactose, holding at 86°F. (30°C.) for 1 hour (the forced crystallization period), followed by rapid agitation and cooling. This procedure results in the formation of very small crystals of alpha-lactose which do not give the impression of coarseness when consumed.

Dry milk contains a very high percentage of lactose, approximately 38 per cent. Because dry milk is dried very rapidly, almost instantaneously, in commercial practice the lactose does not crystallize but forms a lactose "glass." This lactose "glass" is actually a highly concentrated solution of lactose so viscous that crystallization does not occur. It is very hygroscopic, however, and if held in an atmosphere of high relative humidity it will rapidly take up water. Under these conditions the lactose "glass" may become sufficiently diluted to the point where it becomes sticky and finally crystallization of the alpha-lactose occurs. The result of this crystallization of alpha-lactose is a hard-caked powder which is a very serious defect in the product.

The common lactose of commerce is the alpha-hydrate form. However, a beta-lactose is prepared to supply the demand for a more soluble form.

ASH OR MINERAL MATTER (SALTS OF MILK)

If milk is dried first, then the residue burned, a white powder, which is the ash or mineral part of the original milk, remains. If careful weights are taken it will be found that the percentage of mineral is about 0.7. Further chemical study would reveal that this ash is a complicated mixture containing a number of metallic elements, in fact, the same ones found in the animal body.

The procedure followed in determining the ash content of milk makes it extremely difficult to determine the exact combinations that exist in the original product. Milk ash is known to contain potassium, sodium, calcium, magnesium, chlorine, phosphorus, and sulfur in relatively large amounts. There are present small amounts of iron, copper, zinc, aluminum, manganese, cobalt, and iodine, while traces of silicon, boron, titanium, vanadium, rubidium, lithium, and strontium have been reported as present.

Parts of the calcium and phosphorus are combined with the proteins. The remaining portions of these elements, together with the magnesium, are partly in suspension and partly in solution. The potassium, sodium, and chlorine are entirely in solution. The small quantity of sulfur enters into the composition of the casein and lactoglobulin.

Uses of Milk Ash. The ash of milk is not used commercially. It is, from the standpoint of nutrition, however, one of the most important constituents of milk. A sufficient supply of minerals in the human diet is a matter of great importance. Diets based largely upon cereal-grain products are especially lacking in calcium. Milk shares with leafy vegetables the distinction of being the best source of supply for this important element. Milk is, however, low in iron, and for this reason would not supply all the needs of an adult. The newborn is supplied with a store of iron sufficient to tide it over until foods furnishing more liberal quantities of iron are added to the diet.

The ash constituents of milk are extremely important in their relation to the heat stability of milk. This fact becomes of considerable practical importance when milk is subjected to such temperatures as are used in the sterilization of evaporated milk.

When milk is used for butter making, the ash necessarily goes with the skim milk and buttermilk, leaving small percentages of the original milk ash in the butter. In cheese making most of the ash goes with the whey, although the amount in the cheese is much greater than that which goes into butter. The well-known value of skim milk and buttermilk as supplementary feeds for swine and poultry depends in part upon the presence of the milk ash and its importance in making up the deficiencies in mineral content of the grains which compose the chief part of the usual rations.

MINOR CONSTITUENTS OF MILK

In addition to the major constituents, water, protein, sugar, fat, and ash, milk contains a number of constituents which are of minor importance, particularly with regard to the proportions in which they occur in milk. From the standpoint of the chemical and physical properties of milk, it is apparent that some of these minor constituents are exceedingly important. For example, the yellow color of milk is due to a pigment known as "carotene." It is possible to measure quantitatively the amount of carotene in milk.but its presence in small or large quantities materially influences the yellow color of milk.

Phospholipids. The principal phospholipid contained in milk is lecithin, a fat-like substance which contains nitrogen and phosphorus. Lecithin is closely associated with the fat, doubtless making a portion of the concentrated colloidal layer surrounding the fat. Upon the separation of milk, the lecithin becomes more concentrated in the cream, a trace being left in the skim milk. During the agitation of cream in churning, the lecithin is rubbed off the fat globule, and as the fat globules coalesce most of the lecithin remains in the buttermilk. A small portion only is retained in the butter, which contains but a trace (0.03 to 0.05 per cent) of lecithin. Buttermilk, however, has been shown to contain approximately 0.2 per cent owing to the increased concentration which takes place.

The fact that the lecithin content of buttermilk is relatively high probably accounts for the richness of flavor, which is greater than can be attributed to the milk-fat content. It further explains the observed fact that the fat determination of buttermilk and skim milk by the Babcock test gives lower figures than the determination made by the ether extraction method.

Though butter contains but small amounts of lecithin, it is of great significance. Fishy flavor in butter, a rather common defect at times responsible for large losses on the market, has been shown to be due to the decomposition of lecithin. In the splitting of lecithin, trimethylamine is formed. This is the compound responsible for the fishy flavor. This same flavor is sometimes produced in other dairy products such as evaporated milk.

Cholesterol. Milk has been shown by Denis and Minot to contain cholesterol. These authors report cholesterol as occurring in milk in direct proportion to the amount of fat present. They report milk as containing from 105 to 176 parts per million of cholesterol.

Pigments. Milk contains two pigments, one of which is fat-soluble, and the other water-soluble. The fat-soluble pigment of milk belongs to a group known as "carotenoids" and has been designated as "carotene." Carotene is responsible for the yellow color of milk fat. It does not occur in the milk of all species, as the milk of the goat, ewe, and camel, for example, are colorless.

Carotene is not synthesized by the cow, but by plants, and finds its way from the feed into the blood stream and, thus, into the milk. This pigment is deposited in the body fat of cattle, the amount varying with the breed as does the amount in the milk fat. The body fat of the animals of the Jersey and

Guernsey breeds is very highly colored, so much so as to cause objection by consumers when it is placed on the market. It appears that the yellow color of milk is very nearly in direct proportion to the amount of the pigment received by the cow in feed. Such feeds as green grass, green alfalfa hay, soiling crops, green-corn fodder, green silage, and carrots are rich in carotene. Hay which has lost its green color, dry-corn fodder, all kinds of straw, corn (either yellow or white), wheat, oats, beet pulp, bran and oil meals are all feeds low in carotene. It should be explained that the color of yellow corn is due largely to xanthophylls which do not find their way into milk fat in sufficient quantities to influence the yellow color.

The water-soluble pigment of milk has been shown to be riboflavin, previously called "lactoflavin" or "lactochrome," and occurs in the serum, or whey, contributing a yellowish-green tint to this portion of milk. The amount of this pigment occurring in milk is very small, amounting to but 0.05 to 0.1 per cent. Riboflavin occurs in the milk not only of the cow but of most mammals. Its presence in milk cannot be connected directly with the feed the animal receives. There is some relationship, however, between the riboflavin content of milk and high-protein feeds.

Enzymes of Milk. Substances known as "enzymes" are apparently normal constituents of milk. Enzymes are chemical substances secreted by living plant and animal cells which stimulate chemical reactions without becoming a part of the compounds formed. Common examples of enzymes are ptyalin of the saliva, which acts upon starch, forming maltose; and pepsin found in the stomach, which assists in the breaking down of proteins. One of the first enzymes demonstrated as occurring in milk was galactase, a proteolytic enzyme. Russell and Hastings were the first to contend that galactase was present as a normal constituent of milk. The enzyme is thought to play an important part in the ripening of cheese. Lipase, a fat-splitting enzyme, has been shown to be a normal constituent of the milk of cows that have been in milk for an abnormally long period. When this enzyme occurs in milk it may be the cause of a bitter flavor developing. Extreme cases of rancidity in butter, also, have been attributed to the action of lipase.

It has been established definitely that milk contains catalase, an oxidizing enzyme, and reductase, a reducing enzyme. There is some evidence, too, that milk contains lactase, a sugar-fermenting enzyme; diastase, a starch-splitting enzyme; and peroxidase, an oxidizing enzyme. The presence of these last three enzymes mentioned, however, is often disputed. Raw milk contains phosphatase, which is inactivated by proper pasteurization. This inactivation serves as the basis of a test for evaluating the effectiveness of pasteurization.

Vitamins. Milk contains vitamin A, vitamin B_1 (thiamin), vitamin B_2 or G (riboflavin), nicotinic acid (niacin), vitamin B_6 (pyridoxine), pantothenic acid, vitamin C (ascorbic acid), vitamin D, vitamin E (alpha-tocopherol) and vitamin K. The feed is known to be a factor influencing the amount of some vitamins in milk.

Gases. Milk contains from 7 to 10 per cent by volume of gas. Carbon dioxide is present in milk as it comes from the udder, while nitrogen and oxygen are taken up by the milk during milking. On standing, the amount of gas becomes less.

In addition to the above gases, milk may absorb gaseous odors from the air and, although such conditions are abnormal, the fact remains that the market quality of milk may be seriously handicapped by absorbed gases.

Gases may also be formed in milk by certain bacteria. The detrimental effects of these gases, however, are not apparent for several hours after the milk is produced.

Non-protein Nitrogenous Substances. Milk contains a group of nitrogenous substances in addition to the proteins. These substances do not occur in large quantities but they are known to be present. The non-protein nitrogenous substances of milk may be listed as follows: urea nitrogen, amino nitrogen, creatinine, creatine, uric acid, adenine, and guanine. These substances are measured in parts per million, ranging from 1.5 to 10 in milk.

CHAPTER III

FACTORS INFLUENCING THE COMPOSITION OF MILK

If a number of milk samples were gathered from different sources and subjected to careful chemical analysis, it is probable that not a single sample would have exactly the composition given as typical for average milk. If the samples were taken from mixed milk which included the product of numerous cows, especially if representing various breeds, the variation from the average figures might be small. The largest variation from the average figures would be found if the samples, which were analyzed, represented single milkings of individual cows of various breeds.

A study of the result from the analysis of a group of samples taken as suggested would show, first of all, that the samples in all cases contained the same constituents, and, further, that the range of variation is especially large with certain constituents. The nature and composition of milk has interested investigators and has been a subject of researches since the earliest days of science. Not much progress was made until the latter part of the nineteenth century when the development of chemical methods made possible rapid advances toward an understanding of milk and its properties. If one should ignore the present knowledge of the subject, and begin a study of the variations in the composition of milk with the purpose of covering the entire field, it would be found that years of work would be required to accumulate knowledge equal to that now available. Anyone who has conducted research work in this line realizes that even though the present knowledge of the subject is extensive, much remains for future discovery.

Importance of Variations in Composition. The importance of knowledge concerning variations in the composition of milk is evident. Milk is used for food and as the material from which various dairy products are manufactured. If milk varies widely in composition, it is clear that the food value will also vary, and it becomes a matter of economic importance when the product is placed on the market. Wide variations in the composition of milk would also be of significance in connection with the use of milk in the human diet, especially when it furnishes a large part of the food intake, as it does for infants. In the field of dairy manufacturing, milk, as the raw material from which the finished product is made, receives the same close scrutiny as would the materials for manufacture in any other line. For example, because of the wide variations in the fat percentage of milk in most parts of the world, tests for fat content are made when the milk passes from the producer to the manufacturer or dealer.

Nature of the Variations. As pointed out, variations in the composition of milk are largely quantitative rather than qualitative. That is to say, milk from every source, regardless of breed or even of species, will contain the same classes of constituents. An ordinary chemical analysis of milk includes determinations of fat, protein, sugar, and ash. All of these will be found in any sample. If the chemical study is carried further, however, for example, to a study of the nature of the proteins or the characteristics of the fat, decided differences will begin to appear.

The following figures give the average composition of cow's milk limited to the major constituents, and the normal range of composition:

AVERAGE COMPOSITION AND NORMAL RANGE

	Average percentage	Normal range, percentage
Water	87.25	89.50 to 84.00
Fat	3.80	2.60 to 6.00
Protein	3.50	2.80 to 4.00
Lactose	4.80	4.50 to 5.20
Ash	0.65	0.60 to 0.80

The widest variations occur with the fat, the next, with the protein, followed by those of the lactose and ash. It should be understood that variations that considerably exceed the figures given as the normal range occasionally are found. Such extreme variations are associated most often with the beginning or end of the lactation period or represent a single milking from an individual cow that, because of some unknown physiological or pathological condition, temporarily secretes milk far from a normal composition. Mixed milk, representing a group of cows, nearly always will have a composition within the given normal range. If the milk is from cows which all represent the same breed, the range in composition will be decidedly less than when more than one breed is included. Much time and effort have been given to studying the factors responsible for the variations, especially in fat content, which are so commonly found. Certain well-established causes have been determined. These are presented in paragraphs which follow.

Species of Animal. A comparison of cow's milk with that of other species is interesting and valuable at times. Table I, compiled from various sources, gives the composition of human milk and that from common domestic animals. It should be noted that human milk is decidedly low in protein as compared to cow's milk, somewhat lower in fat content, but decidedly higher in lactose. These marked differences are taken into account when cow's milk is modified for infant feeding. In general, the protein content is reduced by the addition of water. Cream is added to restore the fat percentage and the amount of sugar necessary to bring this constituent near to the normal for human milk.

TABLE I. COMPOSITION OF MILK OF VARIOUS SPECIES

Species	Water, percentage	Fat, percentage	Protein, percentage	Lactose, percentage	Ash, percentage
Human	88.30	3.11	1.19	7.18	0.21
Cow	87.25	3.80	3.50	4.80	0.65
Goat	87.88	3.82	3.21	4.54	0.55
Sheep	80.82	6.86	6.52	4.91	0.89
Mare	90.70	1.20	2.00	5.70	0.40
Water buffalo	76.89	12.46	6.03	3.74	0.89
Reindeer	67.20	17.09	9.89	2.82	1.49
Camel	87.61	5.38	2.98	3.26	0.70
Sow	84.09	4.55	7.23	3.13	1.05
Bitch	78.88	8.56	6.82	4.09	1.08
Cat	81.63	3.33	9.08	4.91	0.51

The goat ranks next to the cow in importance as a producer of milk for human food. It is interesting to note that the composition of the milk, as given, closely approximates that of cow's milk. It should be stated that the milk from other species varies nearly as much as does cow's milk, and the figures given are merely average analyses obtained under one set of conditions. For example, the fat content of goat's milk as given in the literature ranges from 3 to 6 per cent. The question of breed evidently is an important factor in this case. The difficulties in getting fair samples of milk from the smaller animals greatly depreciates the value of the figures given for these species. The water buffalo is an important source of milk for human food in the Orient, and it is interesting to note the very high fat content in the milk of this species. The yield, however, is small compared to that from the cow as developed in Europe and America. Mare's milk is low in dry matter, especially fat and casein, in comparison with the milk of the cow. Mare's milk, however, is an important article of food for the tribes of Central Asia. A fermented drink, known as "koumiss," made from this milk is used widely. The milk of the sheep serves as human food in some localities. In these regions, breeds have been developed for this particular purpose. Roquefort, a well-known and highly esteemed cheese, is made in France chiefly from sheep's milk.

Influence of Breed. It is a well-known fact that the breed is one of the most important factors influencing the composition of milk. So important is this influence that the value of any average figure given for the composition of milk has but a limited value. In the northern states, where Holstein-Friesian blood predominates among the dairy herds, the fat and protein content of the milk as it comes to market is distinctly below the average figures usually given, while in the South, where milk from Jersey cows constitutes the larger proportion of the general supply, exactly the reverse is true.

Table II, a compilation based upon the work of several authors, gives the average composition of the milk from the breeds of cattle most common in America. It will be noted that the fat percentage varies widely, the protein considerably, but less than the fat, while the range of variation for the lactose and ash is relatively narrow. The composition of milk is a factor of great importance in the value of milk for manufacturing purpose, or for food. Those breeds producing milk with a high fat content produce less milk than those producing milk with the lower fat percentages. There is also some tendency, although less marked, toward this same relationship within the breeds.

TABLE II. BREED AS A FACTOR IN MILK COMPOSITION

Breed	Water, percentage	Total solids, percentage	Fat, percentage	Protein, percentage	Lactose, percentage	Ash, percentage
Holstein........	88.07	11.93	3.45	3.15	4.65	0.68
Guernsey.......	85.45	14.55	4.98	3.84	4.98	0.75
Jersey..........	85.43	14.57	5.14	3.80	4.87	0.76
Ayrshire........	87.28	12.72	3.85	3.32	4.90	0.65
Shorthorn.......	87.19	12.81	3.80	3.32	4.99	0.70

The relation of the several constituents to the total dry matter of the milk and to each other is of considerable importance. This relationship, so far as the chief constituents are concerned, is set forth in the tabular statement which follows:

THE COMPOSITION OF MILK FROM VARIOUS BREEDS IN TERMS OF TOTAL SOLIDS

Breed	Fat, percentage	Protein, percentage	Sugar, percentage	Ash, percentage
Holstein.................	28.9	26.4	39.0	5.7
Guernsey...............	34.2	26.4	34.2	5.1
Jersey....................	35.3	26.0	33.4	5.2
Ayrshire.................	30.2	26.1	38.5	5.1
Shorthorn...............	29.6	25.9	38.9	5.4

Calculations are based on Table II.

The figures show the differences between milk of several breeds; for example, in Jersey and Holstein milk it is not merely a question of water content. The solids also vary in composition. This is borne out by the fact that in average Jersey milk the fat constitutes 35 per cent of the total solids, while in Holstein milk the fat represents only 28 per cent of the total solids. In the case of Jersey milk the fat represents the greatest single portion of the total solids, while in the milk of the Holstein, Ayrshire, and Shorthorn the milk sugar or lactose constitutes the principal part of the total solids. The per cent of ash in the total solids of Holstein milk is greatest of all in the above breeds.

Influence of Breed on Fat. As pointed out in connection with the discussion of fat, breed is the most important factor influencing the size of fat globules. As illustrated in Fig. 8, the Jersey fat globule is the largest, while the Holstein, among common breeds, stands at the other extreme. The difference between these two breeds in this respect is sufficient to make possible the differentiation of typical Holstein from Jersey milk by the use of an ordinary compound microscope. The practical significance of the size of the fat globules is pointed out in other connections. Although some evidence may be found of breed influence upon the nature of the fat the variations are not marked, and other factors, especially feed and stage of lactation, greatly overshadow the effects of breed. Furthermore, there is no evidence to indicate that such variations in fat composition as may be attributed to breed are of significance either from the standpoint of using milk directly for food or for manufacturing purposes. The chief breed effect upon the nature of the fat appears to be a slightly higher proportion of volatile acids in the fat from the Jersey and probably the Guernsey breeds.

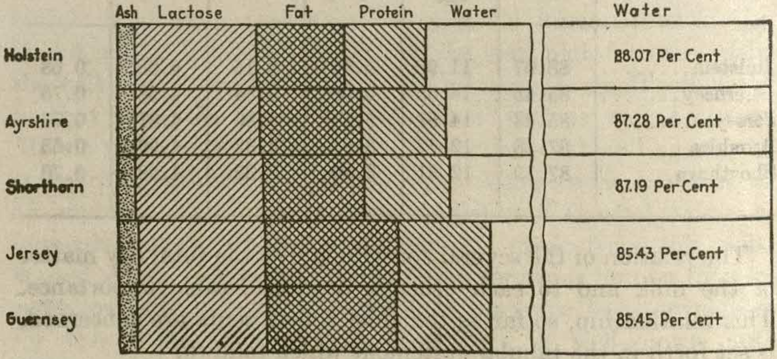


FIG. 10. The relation of breed to milk composition. The ash is practically uniform and the variation in lactose not pronounced. The widest range is in fat and the second in protein. This graph is based upon Table II.

Breed in Relation to Color. Next to feed, the breed is the most important factor determining the amount of yellow color in milk.

The Guernsey breed ranks first in this respect, followed by the Jersey. The Holstein and Ayrshire show the least color, with other breeds intermediate. As explained elsewhere, the cow does not make the yellow color as it is entirely a plant product. The cow passes more or less of it, when it is present, through the body into the milk and body fat. The relatively smaller amount of yellow color in Holstein milk is to be attributed to a greater destruction or elimination of the pigment from the feed by this breed as a result of some physiological process. The pigment is decidedly important as a factor in marketing milk and cream. Because of the practice of maintaining a uniform color in butter and cheese by the addition, when necessary, of a harmless coloring matter, the breed variation in the amount of pigment secreted into the milk is of little economic importance where milk is used for manufacturing purposes.

Breed and the Quality of Dairy Products. As was previously pointed out, there is no significant breed variation in the nature of the fat, with the exception of the yellow color. Although the proportion of other constituents also varies, no evidence is at hand to indicate any difference in the composition and qualities of these constituents. For these reasons, it would follow that the only special relation that the breed might have to the use of milk for food or for manufacturing purposes would depend upon the amount of the constituents present and possibly to their relation to each other. For cheese making, for example, the higher fat content in proportion to the proteins results in a cheese of better quality, but the yield in proportion to the fat is somewhat smaller. This raises some questions regarding the fairness of paying for milk to be used for cheese making upon the basis of the fat content.

In making condensed milk, the relation of the fat to the other solids is also a question of some importance. When the fat is higher in proportion to the solids-not-fat, in order to meet the legal requirements for solids other than fat, the fat content is unnecessarily high. For this reason, milk of a medium fat content generally is preferred to one having a very high fat percentage.

The Stage of Lactation. The period from the time the calf is born until the cow ceases to give milk is called the "period of lactation."

Colostrum. The milk produced by an animal immediately after parturition and for the three to ten milkings following is termed "colostrum." The composition of colostrum differs from normal milk in that it is lower in water, sugar, and fat, and higher in casein, albumin, globulin, and ash than normal milk. The most striking difference between normal milk and colostrum is the globulin which often reaches 12 to 13 per cent in the colostrum. The average composition of colostrum is as follows: total solids, 28.31 per cent; fat, 3.37 per cent; casein, 4.83 per cent; albumin and globulin, 15.85 per cent; sugar, 2.48 per cent; and ash, 1.78 per cent.

Colostrum also differs considerably from normal milk in appearance and general properties. It has a reddish-yellow color, an abnormal odor, a bitter taste, is very slimy and viscous, and has a decidedly acid relation. Because of its high total-solid content, colostrum also has a much higher specific gravity than normal milk, or approximately 1.079.

When examined under the microscope, colostrum shows a large number of colostral cells which according to some writers is due to a sloughing of the epithelial cells of the udder. Others believe that these cells are leucocytes enlarged by absorption of fat globules. The fat globules appear as large, irregularly

TABLE III. STAGE OF LACTATION IN RELATION TO MILK YIELD AND FAT PERCENTAGE[1]

Month of lactation	Average daily milk yield, pounds	In terms of percentage	Fat content, percentage
1	32.9	99.6	4.07
2	33.0	100.0	3.94
3	30.3	92.0	4.06
4	28.4	86.0	4.00
5	27.0	82.0	4.10
6	24.7	75.0	4.10
7	23.4	71.0	4.17
8	22.7	69.0	4.20
9	21.1	64.0	4.20
10	17.1	52.0	4.50
11	11.3	34.0	4.59
12	3.8	11.5	4.70

[1] Data from a group of cows that calved again within a 12-month interval.

shaped masses of fat in colostrum as compared to the round, distinct fat globule of normal milk. Also, it has been found as the result of recent investigations that the colostrum contains antibodies which serve to protect the new-born calf against the invasion of bacteria, until the animal itself develops a resistance. It is this property that especially makes it important that the new-born calf secure the colostrum from its mother.

Stage of Lactation and the Fat. It is well understood that certain changes in the fat accompany the advance in the lactation period. One such change concerns the size of the fat globules. A fresh cow secretes relatively large fat globules. There is considerable decrease in size until about the second month. From this point on, the decrease is less marked until near the close of the lactation period, when the decrease again becomes more rapid. The small fat globules in milk near the end of the lactation period are one cause of the difficult churning often experienced, especially under farm conditions.

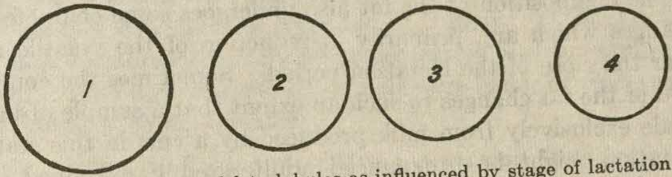


FIG. 11. Relative size of fat globules as influenced by stage of lactation: (1) first month in milk, (2) fifth month, (3) ninth month, (4) twelfth month. The size of the fat globules is a factor in gravity separation of cream and in the time required for churning.

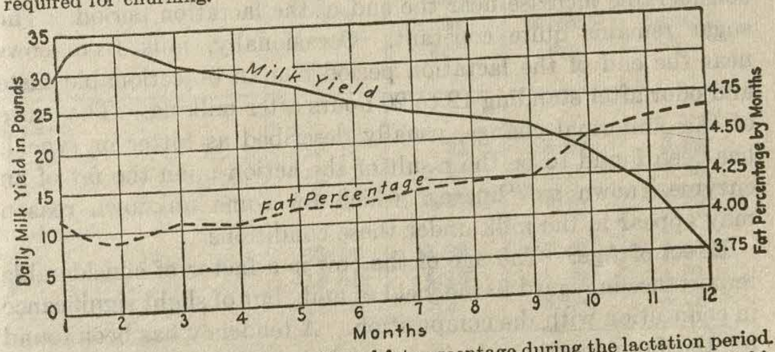


FIG. 12. Changes in milk yield and fat percentage during the lactation period. The maximum milk production is reached by the end of a month and from this point gradually declines. The fat percentage remains fairly constant until near the end of the lactation, then rises to the end.

The fat percentage also is affected in a rather characteristic manner by the stage of lactation. In the colostrum it is low, but within a few days it reaches the normal for the individual. If the cow carries considerable body fat, the fat percentage may be higher at first and decline somewhat during the first month. From the time the normal fat level is reached until near the close of the lactation period, the change due to stage of lactation is not marked, but inclines somewhat upwards. A sharp rise occurs, normally, during the 6 weeks or 2 months immediately preceding the point at which the cow ceases to lactate.

The composition of the fat also undergoes some characteristic changes which are, primarily, a reduction of the volatile acids near the close of the lactation period. Sometimes the composition of the fat changes to such an extent that a sample of butter made exclusively from milk produced by a cow in this state of lactation might be pronounced adulterated if examined by a chemist.

The protein content of milk also follows the fat in showing a considerable increase near the end of the lactation period. The sugar remains quite constant. Occasionally, milk from cows near the end of the lactation period has an objectionable taste and odor after standing 12 to 20 hours after milking. The cause of this abnormal change, usually described as bitter or rancid, has been found to be the result of the action upon the fat of an enzyme known as "lipase," which for some unknown reason may appear in the milk under these conditions.

Effect of Age. The age of the cow is a factor of considerable importance in regard to the yield of milk, but of slight significance in connection with the composition. A tendency has been found for the fat percentage to increase slightly from the first to the second or third lactation period. It then remains practically the same until the effects of advancing age begin to affect the animal. If a cow continues to reproduce until 12 years or more of age, some decline in fat percentage nearly always becomes apparent. This is especially the case with the breeds normally having a relatively high fat percentage in the milk. For example, the milk of four Jersey cows averaging 5.2 per cent of fat during their prime gradually decreased as they aged, until at the age of 15 years the fat percentage averaged 4.5. With the exception of this decline in fat percentage neither the composition of the milk nor the nature of the constituents shows any variations due to age.

Individual Variations. Within the limits of the same breed and with uniform environmental conditions a considerable range of variation may occur, especially in the fat percentage although significant variations are also found in the other constituents. In Table IV is given the composition of the milk from six cows where the ration was the same throughout the year, and all other conditions were maintained as nearly uniform as possible. Every milking was sampled and complete analyses were made of composite samples representing intervals of 7 days. It should be noted that variations occur in the percentage of each constituent reported. If a larger number of animals were included the range would probably be still greater.

TABLE IV. INDIVIDUAL VARIATIONS IN MILK COMPOSITION, TRUE AVERAGE FOR A COMPLETE LACTATION PERIOD

	Total solids, percentage	Fat, percentage	Protein, percentage	Sugar, percentage
Holsteins:				
a....................	12.12	3.23	3.00	5.05
b....................	10.73	2.93	2.70	4.26
c....................	11.35	3.10	3.21	4.25
Shorthorns:				
a....................	13.08	3.89	3.40	5.04
b....................	13.01	4.13	3.49	4.91
c....................	12.17	3.37	3.28	4.98

The following tabulation shows the range in fat percentage found in the lifetime record of 25 cows of each breed. The first 25 cows having three or more lactation periods were selected alphabetically from the records of the University of Minnesota herd.

It is believed that the conditions under which these animals were kept were sufficiently uniform to justify the statement that these variations from the average were due to some individual characteristic which was a matter of inheritance. Had a larger number of animals been included, it is quite likely that still greater ranges would have been found. Only in exceptional cases, however, would be found these wide variations from the normal. The data are not available for the milk constituents other than fat.

	Average fat percentage	Highest fat percentage	Lowest fat percentage
Holstein	3.27	3.70	2.60
Jersey	5.22	5.97	4.37
Guernsey	4.72	5.20	4.28

The question may arise as to the uniformity in the fat content from the same animal year by year. Daily variations occur and there is also some influence due to age as pointed out in another paragraph. When the true average fat percentages for the entire lactation periods are compared, these factors are largely eliminated and the variation which is found is not large. The figures which follow show the average fat percentage of the milk of four animals, one pair of Jerseys, the other Holsteins, for a term of years. These pairs were selected to include, in both cases, one cow with milk above and one below the average in fat percentage

Jerseys (*a*) 4.6; 4.6; 4.4; 4.7; 4.3; 4.4; 4.5; 4.2.
(*b*) 5.6; 5.6; 5.5; 5.0; 5.1; 5.2; 5.0.
Holsteins (*a*) 2.4; 2.4; 2.7; 2.7; 2.6.
(*b*) 3.8; 4.0; 4.1; 3.6; 3.6; 3.5; 3.4.

Seasonal Variations. When milk is sold according to the fat content it is noted, generally, that the fat test drops soon after the cows go out to pasture. Toward fall the test again rises. One often makes the mistake of attributing this decline in the test to the watery nature of the feed when the cows are eating grass, and the rise towards fall as the result of feeding grain or other dry feed. It has been proven experimentally that this assumption is not correct. Cows receiving exactly the same ration throughout a year show the same tendency toward a decline in the fat test during the summer and an increase again towards winter. The effect of the season is often obscured by the changes due to the stage of lactation. If the fat percentage is averaged for a large number of milk samples, including those from cows freshening at different periods of the year, it will be found

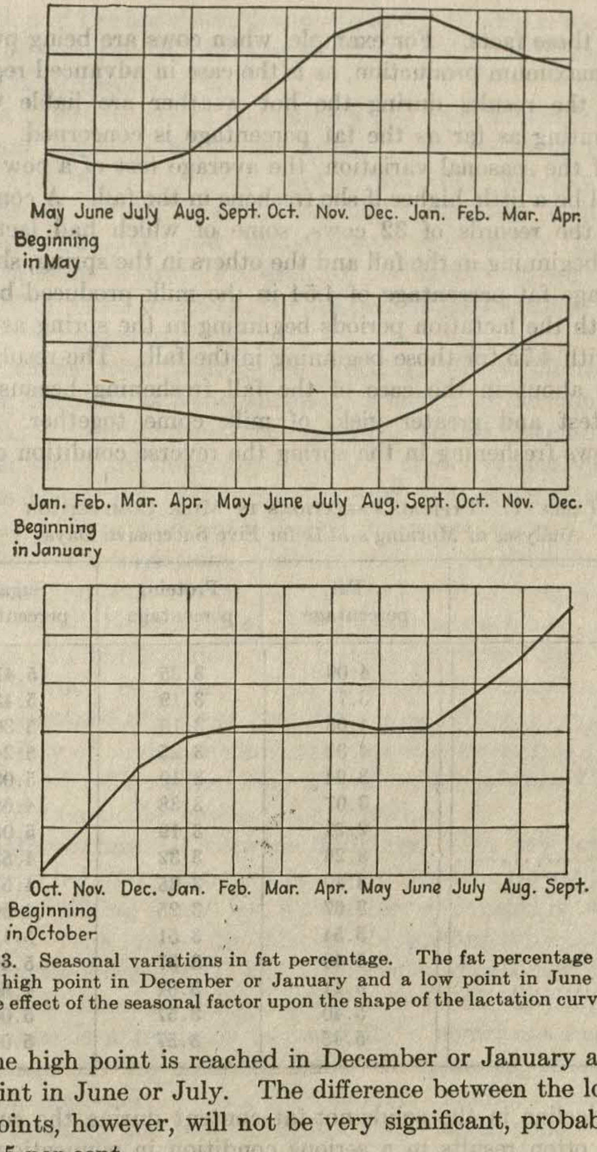


FIG. 13. Seasonal variations in fat percentage. The fat percentage tends to reach a high point in December or January and a low point in June or July. Note the effect of the seasonal factor upon the shape of the lactation curves.

that the high point is reached in December or January and the low point in June or July. The difference between the low and high points, however, will not be very significant, probably less than 0.5 per cent.

Seasonal Variations in Solids-not-fat. It has been shown by White that the solids-not-fat follow the same general seasonal curve as does the fat. There are a number of important applications of these facts. For example, when cows are being pushed for the maximum production, as is the case in advanced registry testing, the results during the hot weather are liable to be disappointing as far as the fat percentage is concerned. As a result of the seasonal variation, the average test of a cow for a year will be a little higher if she freshens in the fall. A compilation of the records of 32 cows, some of which had lactation periods beginning in the fall and the others in the spring, showed an average fat percentage of 4.54 in the milk produced by the cows with the lactation periods beginning in the spring as compared with 4.75 for those beginning in the fall. The results are brought about in the case of the fall freshening because the higher test and greater yield of milk come together. With those cows freshening in the spring the reverse condition exists.

TABLE V. TYPICAL VARIATIONS IN MILK COMPOSITION
Analyses of Morning's Milk for Five Successive Days

	Fat, percentage	Protein, percentage	Sugar, percentage
Ayrshire	4.09 3.71 4.08 4.01 3.94	3.25 3.19 3.19 3.25 3.19	5.41 5.43 5.30 5.24 5.08
Holstein	3.07 2.71 3.26 3.49 3.67	3.38 3.19 3.32 3.25 3.25	4.65 5.05 4.53 4.53 4.50
Jersey	5.54 5.40 5.11 5.40 5.45	3.51 3.57 3.64 3.57 3.57	5.11 5.40 4.66 5.00 5.03

The decline in the solids-not-fat content during the summer months often results in a serious condition in connection with milk standards. The legal requirement regarding solids-not-fat often is placed so high that at times during the summer a considerable portion of a particular milk supply may be below standard which may result in controversy and penalties for violation of the law when the source of the trouble is the normal seasonal variation in milk composition combined with a standard which is unreasonably high.

In a report by one of the authors attention was called to the seasonal variation in fat percentage, and the suggestion was made that temperature and relative humidity probably are the responsible factors. Later, carefully controlled experiments by Hays, Ragsdale, and Brody showed conclusively the importance of temperature. For each 10° decline in temperature from 72 to 27°F. (22.2 to 2.8°C.) the fat percentage increased approximately 0.2 per cent.

Variations from Milking to Milking. In addition to the factors discussed as responsible for variations in the composition of milk, certain changes occur from day to day because of conditions which are unknown. Table V shows typical variations of this character. All factors of feed and environment were kept as uniform as possible during the period covered by these samples. The variations, while not extreme, are noticeable and would be important in an attempt to secure a sample of milk which would be typical of the animal in question. If more animals and longer periods were included, greater ranges unquestionably would be found. These unavoidable variations suggest the importance of correct procedure in sampling, especially the desirability of having the milk samples used for testing prepared from mixed milk representing several milkings when the dairy value of a particular cow is to be judged.

Length of Interval between Milkings. The fat content of milk secreted by a particular cow may show considerable variation from milking to milking, if the interval is varied between the milkings. The longer the interval the greater the quantity of milk and the lower the fat test. As a rule, when a cow is milked at 12-hour intervals little variation is found, although with some animals a tendency is found for a somewhat higher fat percentage in the morning milk. In practice, some dairy farmers, especially during the summer months, milk early in the morning and late at night. Under these conditions one interval may be 9 or 10 hours and the other 14 or 15, resulting in a variation in fat percentage of as much as 0.75 or 1.00 per cent. In taking samples for testing, this possibility of variation has to be taken into account. A sample from a single milking may be far from a true average. When milk is sold at retail, care also must be exercised so that mixed milk is used, otherwise dissatisfaction on the part of consumers will result. When cows are milked three or four times within the 24-hour period, the fat percentage is somewhat higher than would be the case with two milkings daily. With heavily producing cows, the added milkings also result in a considerable increase in quantity, but in case the milk production is small, no significant increase is obtained by the additional milkings. The variation due to the length of the interval between milkings appears to apply only to the fat content.

First and Last Milk. The first milk drawn from a cow is low in fat while the last milk drawn, generally called the "strippings," is very high. The range in fat percentage depends upon the milk yield of the particular cow; the higher the yield the greater the variation from foremilk to strippings. One of the authors found that cows producing approximately 40 pounds of milk daily yielded foremilk containing, on the average, 1.45 per cent of fat compared to 6.15 per cent in the strippings from the same cows. No difference was found in the nature of the fat or in the composition of the milk serum. The importance of a knowledge of the variation in question arises in sampling milk or in connection with methods of milking. If care is not taken to secure the strippings at the time of milking the fat percentage of the entire quantity may be appreciably lowered.

Fatness of Cow at Parturition. It has been definitely proven that the condition of flesh of the animal at the time when lactation begins sometimes has a quite marked, though temporary, effect upon the fat content of the milk. The most noticeable results occur only when the cow is excessively fat at the time and is by nature a liberal producer of milk. A fat test covering a period as long as 7 days, if begun within a week after the birth of the calf may, under such conditions, be one-half higher or even twice the normal for the animal. Many examples could be taken from records of advanced registry showing a fat percentage varying from 5.0 to 6.0 per cent for 7 days when the average for the entire lactation period of the same animal was 3.4 to 3.6 per cent. When this abnormally high fat percentage results from high flesh of the cow, a gradual change toward the normal occurs. That point is reached in 15 to 30 days following the time of freshening. Unless these facts are understood samples for testing that give a wrong impression of the richness of the milk from a certain cow may be taken and buyers of breeding stock may be deluded regarding the merits of particular animals because of records of fat production made during this period of abnormal fat percentages.

Feed of the Cow. It would seen entirely reasonable that the richness of the milk should depend upon the nature of the feed. Although the error of this supposition has been shown experimentally for nearly half a century, many practical cattle owners still assume it to be a fact. The fat percentage of the milk produced by any particular cow is a matter of heredity and not of feed. As pointed out in another paragraph, variations due to climatic conditions, known as the seasonal variation, commonly, but erroneously, are attributed to the feed. It is possible by feeding a ration carrying a liberal amount of oils, for example, ground flax or ground soybeans, both of which contain large quantities of oil, to raise the fat percentage a trifle, perhaps 0.2 per cent, and with some individuals more. This is too small, however, to be of any practical significance. No experiment station investigator has found a definite means of increasing permanently the fat content to any significant extent by methods of feeding. The value of good feed and care is reflected in the yield of milk, not in the richness of the product. The proportion of other major constituents, likewise, is unaffected by the feed. The great importance of the mineral matter from the standpoint of human diet has often raised the question regarding the possible variations of these constituents from the normal. The available evidence indicates that even under extreme conditions of mineral intake with the ration the ash content of the milk produced remains normal. In the course of an investigation by one of the authors, analyses were made of milk produced by cows suffering extremely from a deficiency of phosphorus in the ration. The mineral content of the small amount of milk produced was entirely normal. Iodine added to the ration has been found to increase the amount of this element in the milk, but in this case it is not as a part of the normal mineral content. The reason for this stability in the composition of the milk is explained, in part, by the fact that it is produced from the blood and it is a well-known physiological fact that blood remains essentially the same in composition. If the ration of the cow is temporarily deficient in certain constituents, minerals, for example, the reserve of the body is used. In cases of long continued deficiency in supply, milk secretion slows up and finally ceases.

Some Effects of Feed upon Milk. Feed does, however, have some important and well-known effects upon the milk. One concerns the yellow color. The amount of this pigment in the fat is dependent upon the amount in the feed, leaving out of consideration breed variations. Other products not normally found in milk may also come from the feed; for example, volatile oils from onions, turnips, or rape, and at times from other plants which may convey characteristic tastes to the milk or manufactured products. These substances however, are not normal milk constituents and are dissolved only in the fat or serum.

Feed also may exert quite a pronounced effect upon the nature of the fat itself, as pointed out elsewhere. For example, fresh pasture grass results in softer milk fat and, consequently, butter that melts at a relatively low temperature. Cottonseed meal produces milk fat with a very high melting point and butter that will stand up at relatively high temperatures. Certain other feeds have more or less pronounced effects, although when fed as part of a ration it is only occasionally that special effects are noted.

Miscellaneous Causes for Variations. A number of other less important factors sometimes are responsible for variations in milk composition. Among these are change of milkers, fright of the animal at milking time, sickness, oestrum, or the administration of drugs. The direction and extent of the variations from these causes are not constant and cannot be predicted. Sickness, for example, may result in either an abnormally low or high fat content. Frightening the animal at milking time usually lowers the fat percentage as a result of some of the richer strippings not being secured by the milker. A change of milkers often gives similar effects. At the oestrum or heat period, the composition of the milk is sometimes considerably abnormal, or it may remain constant throughout this interval. There are some reasons for suspecting that changes of a more fundamental character than variations in fat percentage may accompany oestrum, and even at times make the milk undesirable for infant food when all the milk used comes from one cow. Certain drugs may influence the fat percentage temporarily, but not without having also an unfavorable effect upon the milk yield. No means is known for increasing the fat yield by means of drugs.

General Discussion. The difficulties encountered in securing a representative sample of milk may be appreciated when one considers the numerous factors known to result in variations in milk composition. When mixed milk is to be sampled, the variations from day to day should be much less than in the case of samples from a single animal, because a sudden variation due to some factor influencing a certain animal may be counteracted by a variation in the other direction by another factor or at least will be reduced by the larger proportion of milk not so affected. Certain factors necessarily affect an entire herd; for example, the effect of the interval between milkings or the seasonal variations. If the majority of the herd freshens, within a short period the mixed milk, ordinarily, would show the typical changes due to stage of lactation. Where large quantities of milk are assembled from numerous herds, for example in a city milk distributing plant, the factors of breed and seasonal effect are about the only ones that can be observed in the composition of the milk which is handled. Sometimes, due to a uniformity of practice regarding time of freshening, this also may be a factor.

CHAPTER IV

PROPERTIES OF MILK

Physical State of Milk. Milk is not only of a complex chemical nature, but, due to the various constituents, its physical nature also is very complicated. Water may be said to be a carrier or dispersion medium for the constituents of milk, and from the standpoint of the chemist, water serves as a continuous phase of liquid in which the constituents are dispersed. The chemist considers that matter exists in three general states of dispersion the limits of which have been set arbitrarily as follows: coarse dispersion, particles greater than 0.0001 millimeter; colloidal dispersion, particles from 0.0001 to 0.000001 millimeter; and molecular dispersion, where the particles are less than 0.000001 millimeter in diameter. All three of these states of dispersion are known to exist in milk.

Among the constituents of milk which are in molecular dispersion or true solution may be listed the lactose, a portion of the mineral salts, and possibly some of the lactalbumin. The proteins of milk, in general, are dispersed colloidally through milk in finely divided particles, of which casein is the largest and albumin and globulin are the smallest. The calcium phosphate is associated with the proteins and also colloidally dispersed. The fat of milk is the only constituent which occurs in the form of a coarse dispersion or an emulsion. In milk, water is the continuous phase and for this reason the emulsion is said to be of the fat-in-water type.

Chemical Reaction of Milk. When milk is freshly drawn from the cow, it shows an amphoteric reaction, that is, it turns red litmus blue, and blue litmus red. Normal fresh milk has a hydrogen-ion concentration of approximately pH 6.5 to 6.6, which indicates that the milk is slightly acid. When normal fresh milk is titrated with an alkali solution using phenolphthalein as an indicator, it appears acid, showing from 0.10 to 0.26 per cent acid, if it is assumed that the acidity is due to lactic acid.

It should be pointed out, however, that perfectly fresh milk contains no lactic acid. The acidity of fresh milk is due to certain constituents of milk some of which give an acid reaction and some of which actually combine with the alkali. The acidity of fresh milk is known to be due to the phosphates of milk, the proteins (casein and albumin), and to a slight degree to the presence in milk of carbon dioxide and citrates. It should be clear to the student, therefore, that the true acidity of milk actually cannot be measured by titrating with a standard alkali solution. The method, however, is followed so commonly in the various branches of the dairy industry that attention is drawn to it at this point and it will be referred to again under the subject of "miscellaneous tests." The practice of titrating milk with an alkali is followed because it is known that after the acidity of milk reaches a point near 0.18 to 0.20 per cent, a large proportion of this acidity is due to the lactic acid formed by the action of bacteria on the lactose.

The wide variation in the acidity of fresh milk may be attributed to the stage of lactation, the composition of the milk, or abnormal conditions within the udder. Colostrum is high in acidity but in a few days following calving the acidity of the milk becomes normal. There is no regularity to changes in the acidity of milk as the lactation period progresses. Certain breeds or individual animals may produce milk which is relatively high in milk solids-not-fat (the proteins—casein and albumin) and such milk may show a high titratable acidity. The milk from animals suffering from mastitis is frequently much lower in acidity than that produced by animals having mammary glands free of the disease. The feed consumed by the cow apparently has no influence on the acidity of the milk produced.

Specific Gravity. Milk is a complex colloidal system in which the dispersion medium, water, contains salts and sugar in solution. It is therefore heavier than water. The specific gravity of milk from mixed herds averages 1.032. From herds it ranges from 1.027 to 1.035, and from individual cows a somewhat wider range will be found. The specific gravity of milk usually is taken at 60°F. (15.5°C.) or corrected to this point, as this is a convenient temperature at which to work in the laboratory. The specific gravity of milk is influenced by the relation of its constituents, each of which has a different specific gravity, approximately as follows: fat, 0.93; lactose, 1.666; proteins, 1.346; casein, 1.31; salts, 4.12.

The average specific gravity of the milk solids other than fat has been given by various authorities from 1.6007 to 1.638.

The specific gravity of a fluid varies with its temperature. Water reaches its maximum specific gravity at 39°F. (3.9°C.). Milk differs from water in this respect in that it does not reach its maximum specific gravity until a temperature of 31.01°F. (−0.55°C.), the freezing point of milk, is reached. As milk fat is the lightest constituent of milk, the more that is present, the lower the specific gravity will be; and in a like manner, the greater the percentage of solids-not-fat, the heavier the milk will be. The specific gravity of a fluid may be determined either by finding the weight of a known volume or by measuring the volume of a known weight. The lactometer makes use of the latter method.

The specific gravity of milk cannot be determined for at least an hour after it is drawn from the cow, owing to the air and carbon dioxide contained in fresh milk.

Taste and Odor of Milk. Normal freshly drawn milk tastes slightly sweet to most people and has a characteristic although not pronounced odor. The odor disappears when milk is allowed to stand a few hours or following cooling and aeration where this practice is followed immediately after milking. It has been shown that the pleasing flavor of milk may be correlated with a high lactose and a relatively low chloride content. A low lactose and a high chloride content probably would mean a milk with a salty flavor. Toward the end of the lactation period the milk produced by a cow often has such a salty taste. A variety of tastes and odors may be found at times, but these must be classed as abnormal. Six sources of these abnormal tastes and odors may be recognized.

1. From the cow herself due to a disturbed physical condition. In this case, the substances giving the objectionable taste are secreted with the milk.
2. From the feed of the cow, in which case the odors or flavors are taken up by the blood and secreted in the milk.
3. From the absorption of pronounced odors to which milk is exposed.
4. From the decomposition of the milk constituents resulting from the growth of bacteria and other microörganisms.
5. From foreign material actually present in the milk.
6. From changes due to chemical action.

Of these, the fifth is of the least importance as it seldom occurs. It is the exception, and not the rule, for the feed to affect the taste and odor. At times it becomes very important, however, even making milk unmarketable. In some localities, the cows eat wild onions or various weeds in the pastures to such an extent that it is a serious matter. Among feeds, otherwise desirable, turnips, fresh rye pasture, and, in fact, fresh pasture grass of any kind, at times produce some undesirable flavors and odors. The third source is also important at times as milk may be exposed to the air of a barn containing undesirable odors, or the same condition may result when milk is stored in an icebox in close proximity to bananas or other aromatic food products. The fourth is the most common of all and the most important as flavors of this class develop in all milk sooner or later. The presence in milk of a foreign substance possessed of a strong objectionable odor may be responsible for milk becoming unfit for food. Such a substance as fly spray used in keeping flies off the cow during the summer months may reach milk and be responsible for such a condition. Certain metals such as iron or copper may contribute metallic flavors or catalyze other changes in flavor. Various chemical reactions may occur in milk and result in pronounced tastes and odors. The "oxidized" flavor of milk apparently is traceable to such a chemical change. More complete discussion of this subject is found in a later chapter.

The Color of Milk. Milk ranges in color from a bluish-white to a golden-yellow, depending upon the breed of animal, the kind of feed, and the amount of fat and solids present. In large quantities milk appears entirely opaque while in thin layers it is slightly transparent. Milk from which the fat has been removed, or milk which is low in fat percentage, shows a bluish tint.

The white color of milk is due to the reflection of light by the dispersed fat globules, the calcium caseinate, and the colloidal phosphate. Any of these constituents when dispersed in the concentrations found in milk cause the liquid to appear "milky."

The Yellow Color. Carotene is the pigment responsible for the yellow color of milk. Carotene, closely associated with xanthophyll, is found in green plants. Carotene is yellow but its presence is overshadowed in plants by the green pigment, chlorophyll. When eaten by the animal, a portion of the carotene finds its way into the blood stream. The pigment is readily soluble in fat and a portion unites with the milk fat to give it the typical yellow color. The depth of color depends upon the amount of pigment present in the blood when the milk is secreted. The same pigment also colors the body fat of cattle to some extent. The pigment, as it occurs in the milk fat, so far as known, is identical, chemically, with that found in the plant. The proportion of the carotene retained in the body varies to some extent with the individual animal and especially with the breed. The Guernsey and Jersey breeds produce fat with the deepest yellow and the Holsteins and Ayrshires the lightest. It is interesting to note that the animals that produce the yellowest milk fat also have the highest color in the body fat.

Some feeds are rich in carotene while others are not. For this reason certain feeds, such as green forage and carrots, tend to produce milk of a deeper yellow color than can be produced, for example, by timothy hay, white corn, or oats. This close relationship between the nature of the feed and the color of milk fat accounts for the well-known seasonal variation in the color of butter. In the spring and summer the cows generally have access to green grass, while during the winter dry feeds are fed. As a result, in the spring the butter is a deep golden yellow and in the winter, unless artificially colored, it is almost white in color in some localities.

The second pigment, lactochrome or riboflavin, occurs in solution in milk but is visible only in whey, to which it contributes a slightly greenish tint. In normal milk the riboflavin is masked by the milk constituents.

The Freezing Point of Milk. Water freezes at 32°F. (0°C.), while milk freezes at temperatures slightly lower, the average being 31.01°F. (−0.55°C.). The range is between 31.1 and 30.9°F. (−0.50 to −0.61°C.). It is of interest to note the way in which milk freezes as compared with water. Should a bucket of water and one of milk be placed at a temperature below the freezing point of each, it will be found that the water will freeze over the surface, while the milk will freeze on the walls of the pail, leaving a core of liquid milk in the center. It will require a very low temperature to freeze the milk completely, since only about 75 per cent of it will freeze at 14°F. (−10°C.). As the milk freezes the solids become concentrated in the unfrozen portion, the water being the portion which freezes. A concentration of the solids of milk might be secured in this way.

The soluble constituents, lactose and ash, determine the freezing point of milk and are responsible for its being lower than that of water. The freezing point of water is affected by the material in solution. By the addition of salt to water, its freezing point can be reduced to exceedingly low temperatures. The fat and proteins have little or no effect on the freezing point of milk. Since the soluble constituents, lactose and ash, vary in milk so slightly, the freezing point remains almost constant. This fact makes it possible to determine whether or not milk has been watered. It has been shown that, with the addition of 1 per cent (by volume) of water to milk, the freezing point rises approximately 0.0099°F. (0.0055°C.). The freezing point determination is, therefore, of importance to those buying milk on the market. Care must be taken, however, that fresh milk is used in connection with the test. It so happens that an increase in acidity results in a lower freezing point. The same is true in case a preservative is added to the milk, as it increases the materials held in solution.

Influence of Freezing on Milk. It is interesting to note the effect of freezing on the flavor of milk. After frozen milk has been melted to its original state, it has a diluted or watered taste. The cream line which such milk will form is much reduced as compared with the same milk not frozen. An examination of the fat globules of frozen milk, as reported by Reid, reveals the fact that they form in clumps or groups and become distorted and irregular in shape. There is a decided rupturing of the fat globules of milk when frozen, a liberation of some free fat, and an apparent effect similar to that of churning. If milk is properly thawed after freezing, the effects of the freezing are less noticeable.

The manner in which cream freezes differs from that of milk, particularly when cream contains 30 per cent or more of milk fat. Cream, under these conditions, freezes more nearly as a homogeneous mass with very little if any migration of the fat or other solids toward the center.

Specific Heat. To raise or lower the temperature of any substance a given number of degrees, a certain amount of heat must be added to or taken from the material. All substances vary in the amount of heat required, because they differ in their chemical nature and their physical state. The ratio between the amount of heat required to raise a given weight of substance to a given temperature and the amount of heat required to raise the same amount of water to the same temperature is termed "specific heat." The unit of heat is known as the "calorie," and is the amount of heat required to raise 1 gram of water from 59 to 60.8°F. (15–16°C.), that is, 1°C. Since water remains the standard, however, the specific heat of a substance is the number of calories required to raise a definite amount of substance through 1° in temperature. It is commonly stated that the specific heat of a substance is the number of calories required to raise 1 gram or 1 pound of substance through 1°C. or F.

It is exceedingly important, however, to bear in mind that the amount of heat required to raise the temperature of a fluid is affected by the specific gravity, or density. Water has its greatest specific gravity at 39°F. (3.9°C.) and it is at this temperature, therefore, that the specific heat of water is taken as the standard with which other substances can be compared. It is important, however, to note the specific heat of a substance at various temperatures. Milk has a specific heat of 0.938 at 59°F. (15°C.), of 0.920 at 32°F. (0°C.), of 0.930 at 104°F. (40°C.), and of 0.918 at 140°F. (60°C). These figures are supplied by Hammer and Johnson, who report the specific heat of other milk products, as indicated in Table VI.

TABLE VI. SPECIFIC HEAT OF MILK AND DAIRY PRODUCTS AT DIFFERENT TEMPERATURES

Product	Specific heat at various temperatures			
	At 32°F. (0°C.)	At 59°F. (15°C.)	At 104°F. (40°C.)	At 140°F (60°C.)
Whey	0.978	0.976	0.974	0.972
Skim milk	0.940	0.943	0.952	0.963
Whole milk	0.920	0.938	0.930	0.918
15 per cent cream	0.750	0.923	0.899	0.900
20 per cent cream	0.723	0.940	0.880	0.886
30 per cent cream	0.673	0.983	0.852	0.860
45 per cent cream	0.606	1.016	0.787	0.793
60 per cent cream	0.560	1.053	0.721	0.739
Butter	0.512	0.527	0.556	0.580
Butter fat	0.445	0.467	0.500	0.530

The differences in the specific heat of the various milk products doubtless are due to their chemical composition. At 59°F.

(15°C.) the specific heat of whey is 0.976; of skim milk, 0.943; 15 per cent cream, 0.923; 20 per cent cream, 0.940; 30 per cent cream, 0.983; 45 per cent cream, 1.016; 60 per cent cream, 1.053; butter, 0.527; and milk fat, 0.467. In this case it is interesting to note that as the fat content of cream is increased the specific heat increases. With skim milk and whole milk, skim milk of a low fat content has a higher specific heat than whole milk. It is of further interest to observe that butter and milk fat containing a small amount of the other constituents of milk have a very low specific heat.

The specific heat of milk is of importance from a practical standpoint, as it is applied in measuring the cost of heating and cooling milk and milk products. Since milk and its products are perishable, it is essential that they be kept cool. The cost of cooling any product is related to its specific heat. Heat is generally expressed, commercially, in terms of the British thermal unit (B.t.u.) which is the amount of heat required to raise 1 pound of water 1°F. Thus, specific heat may be expressed in British thermal units. Since it is worked out fairly definitely as to how much fuel of different kinds is required to produce a given amount of heat, it is comparatively a simple matter for the milk engineer to calculate costs in the heating and cooling of milk and its products. The importance of these cost figures to the industry may be well understood.

Boiling Point of Milk. Milk is slightly heavier than water, and, since the boiling point of a liquid is influenced by factors responsible for its specific gravity, milk boils at a temperature slightly above that of water. Water boils at 212°F. (100°C.) at sea level and average milk at 212.3°F. (100.17°C.). Variations in the boiling point of milk are so slight that they are of little practical importance. The boiling point is of interest only as one of the properties of milk, yet it has some bearing upon the condensing of milk, in which process a portion of the water of milk is driven off in vapor. In calculating the heat required in reducing milk by boiling under vacuum, the boiling point becomes important.

The Effect of Heat on Milk. Milk is influenced by heating in several different ways. When milk is brought to the boiling point in the air, a thin film forms over its surface. This film is due to the coagulation of a small amount of casein, with which are associated a small amount of calcium salts and, in the case of whole milk, milk fat. Should milk be slightly high in acid, it will curdle or coagulate when boiled. This property of milk is the cause of much disappointment to the housewife, who, when attempting to boil milk, finds the utensil containing a cheesy mass in the place of the apparently sweet, fluid milk. In many recipes which include heating of milk to a boiling point, the housewife is instructed to add a pinch of soda to the milk before boiling. By this procedure, the acidity of the milk is reduced to a point where the milk might be boiled without danger of forming a cheesy mass. The temperature at which milk will coagulate, therefore, is closely associated with the acidity. Not only is this fact observed in the home, but it is of tremendous importance in market-milk plants where milk is pasteurized by heating to 145°F. (62.7°C.) and held 30 minutes, after which it is cooled immediately. Milk must be fresh and of low acidity, or it will curdle during the process of pasteurization. In the condensary, milk not only is heated but concentrated by a partial removal of water. The result is a concentration of the milk constituents, including the acid of milk. Concentrated milk coagulates at a lower temperature, therefore, and must possess a low acidity in the fresh product.

Cause of Coagulation by Heat. The coagulation of milk by heat is due to the presence in milk of proteins, principally casein and albumin. Casein is rather stable in milk and its coagulation is not accomplished easily in fresh milk of low acidity by the application of heat until a relatively high temperature, 268 to 280°F., (131 to 137.8°C.), is reached. With increasing acidity, however, casein coagulates at lower temperatures. Albumin is coagulated more readily by heat than casein in fresh milk of low acidity; only small fractions, however, are coagulated at different temperatures under these conditions. Increase in acidity permits a more complete coagulation of albumin by the application of heat.

Mineral Balance as Affected by Heat. Closely associated with the coagulation by heat is the mineral balance in milk. Some authors maintain that there must exist in milk a proper balance between the calcium and magnesium, together with the citrates. Casein is most resistant to heat coagulation when it is in combination with a definite amount of calcium. Since calcium occurs in milk in combination with casein, citrates, and phosphates, a low calcium content results in an improper balance. Under such conditions, the casein of milk may be coagulated slightly by heat. Magnesium may function by replacing the calcium in the citrates and phosphates. Should there exist in milk an excess of calcium, there may not be sufficient citrate and phosphate to combine with the calcium, thus leaving an excess with the casein. The addition of citrates or phosphates to such milk results in a more stable casein by reducing the calcium associated with the casein. It is now an established fact that instability of casein may be due to an excess of calcium and magnesium ions. More recently the stability of casein has been improved by removing the excess of calcium and magnesium from a portion of the milk used in the manufacture of evaporated milk, previous to the heat-treatment, by employing the ionic exchange principal.

The above statements pertaining to the mineral balance of milk have to do with the relation of this balance to the coagulation of casein by heat. There are certain influences, however, on the salts themselves when heat is applied to milk. Closely associated with the coagulation of casein is the precipitation of the calcium salts in milk. In addition, the stability of the colloidal dicalcium phosphate is decreased, which probably causes a precipitation of phosphates.

Other Effects of Heat. Other influences of heat on milk are its effect on the flavor and odor of the milk, the viscosity, and the fat. The most noticeable of these to the average consumer is the influence on the flavor and odor. When milk is heated to temperatures near the boiling point, it acquires a pronounced cooked taste and an odor with which everyone who is acquainted with the odors from the kitchen is familiar. This flavor and the accompanying odor probably are due to the influence of heat on the proteins and lactose of milk. More recent studies indicate that the cooked flavor is due to the formation of sulfides or sulfhydryl compounds which occur when milk is subjected to sufficiently high temperatures. A slight cooked taste and an odor often are noticeable in improperly pasteurized milk.

The influence of heating on the viscosity of milk may be one of an increase or a decrease, depending upon the temperature. The heating of milk to temperatures commonly used in pasteurization results in a decrease in viscosity, while heating nearly to the boiling point results in an increase in viscosity, where acidity may be a factor influencing to a certain extent this increase in viscosity.

The influence on the fat is physical. Fat globules tend to form in clusters. These clusters are broken up to a large extent when milk is heated. It is claimed by some workers that this breaking up of the fat clusters is responsible for the decrease in the viscosity of milk on heating. The creaming ability is noticeably affected when milk is heated to temperatures above 144°F. (62.2°C.), there being a decrease in the volume and a decided increase in the percentage of fat contained in the layer.

Viscosity of Milk. The viscosity of a fluid is its resistance to flow, agitation, or shear. It is a property of all fluids. It may be accurately determined in the laboratory and expressed in terms of the centipoise, a unit of force. Water flows with ease and has a viscosity of 1.005 centipoise at 68°F. (20°C.). Syrup pours much more slowly than water and possesses a greater viscosity. Milk is slightly more viscous than water, approximately 1.5 to 1.7 times more viscous, owing to the presence of the solids in milk, some of which are in solution, others in suspension, and still others in the form of an emulsion. All liquids appear more viscous at low than at high temperatures. Milk is no exception to this rule. Milk is quite different, however, from most fluids in that its original viscosity is partially destroyed under certain conditions, while under others it may be increased. The original viscosity of milk is reduced when milk is heated to temperatures commonly used in pasteurization. On the other hand, when milk is subjected to temperatures such as those reached under pressure, an increase in the viscosity of milk results. When milk is subjected to prolonged agitation the viscosity is reduced. Aging, souring, and the development of certain types of bacteria in milk are responsible for an increase in viscosity. It is conceded, generally, that the increase in viscosity is due to the changes taking place in the proteins of milk, primarily casein, which has hydrophilic properties similar to other proteins.

Practical Importance of Viscosity. Fluctuations in the viscosity have very little relation to the marketing of milk, but viscosity is exceedingly important in the marketing of a few of the products of milk. Cream, for example, is often judged by the consumer by the way it pours. A viscous cream containing 20 per cent fat, appears to the consumer to be much richer than a thin cream of the same percentage of fat. It frequently happens that the consumer becomes suspicious that cream is low in fat content because of its low viscosity. Pasteurized cream, especially, appears thin unless it is aged for 12 to 48 hours at a low temperature. Cream aged in this manner whips with ease, while a freshly pasteurized cream may require more time before it will whip, and the whipped cream will appear watery.

Buttermilk churned from pasteurized cream is much less viscous than buttermilk churned from raw cream. It is not uncommon to hear the complaint from the consumer that buttermilk has been watered when the viscosity simply has been reduced by pasteurization.

To secure a smooth, velvety texture in ice cream, the manufacturer develops a certain amount of viscosity in the ice-cream mixture, before freezing, simply by holding the mixture for 12 to 48 hours at a low temperature. The average consumer believes ice cream to be rich in fat if it has a smooth body, and prefers such an ice cream to one that is coarse and grainy which gives the impression that water was added.

In the manufacture of condensed and evaporated milks, it is important that they possess a certain degree of viscosity, at least, to give the impression to the consumer that large quantities of water were removed in their preparation. It should be clear, therefore, that although the viscosity of fluid milk is of little commercial importance, this property of milk is very decidedly useful in the handling of some of the other dairy products.

Measuring Viscosity. The viscosity of fluids may be measured in several different ways, depending upon the accuracy desired. A relative viscosity may be observed simply by placing a drop of the fluids to be compared on a clean glass plate. The plate then is placed in a perpendicular position and the time required for the fluids to flow a given distance is observed. The MacMichael viscosimeter which measures the resistance of the fluid to the movement of a solid body is far more accurate.

Adhesiveness of Milk. Milk possesses adhesive properties which can be demonstrated easily by moistening a piece of paper with milk and pasting it against a flat surface of wood, glass, or metal. The paper will stick very much the same as though it had been moistened with a small amount of glue. This property of milk doubtless is due to the casein of milk, which is used in rather large quantities in the manufacture of casein glue, one of the strongest glues made.

Effects of Enzymes on Milk. Milk is subject to many changes. The complexity of its composition makes milk subject to the action of all types of enzymes which are either present in milk at the time of production, or produced by microörganisms which find milk an excellent medium in which they may grow. The extent to which milk may be acted upon by enzymes may be realized when it is stated that the proteins, fat, and sugar of milk may be decomposed completely by the action of enzymes. So many by-products may be formed through the decomposition of these products that it would be difficult to attempt to name them. The proteins of milk may be reduced to simpler forms; sugar may become the source of lactic acid, acetic acid, butyric acid, formic acid, alcohol, etc.; fat may be broken down into the fatty acids and glycerol, carbon dioxide, and water.

One of the most interesting actions of enzymes, and one which is used commercially in the manufacture of cheese, is the coagulation of the casein of milk by rennin. It has been estimated that 1 part of pure rennin will coagulate 3,000,000 parts of milk. It has been the practice for years to apply this principle in the home in making so-called "junket" with junket tablets, which consist of powdered rennin.

Doubtless many off-flavors which occur in milk and milk products are linked with the formation of certain enzymes in milk. One very disagreeable defect is a bitter flavor accompanied by a rancid odor, which is brought about in milk by lipase, a fat-splitting enzyme.

Effect of Acids on Milk. The coagulation of milk is brought about readily by acidifying it. One of the first observations one might make in operating the Babcock test is the coagulation of the milk upon the addition of acid. This same change takes place normally in milk owing to the development of lactic acid. The proteins of milk, casein in particular and albumin to a minor extent, are coagulated from milk upon the addition of acid. Should the reaction be severe, however, there will result a complete digestion of the proteins by the acid. In extreme cases, the acid reaction may generate sufficient heat to result in the caramelization of some of the milk sugar.

The normal acidity of milk frequently is reduced with alkalies and it is of interest to observe under such conditions that the coagulated casein returns to a state very similar to that in which it exists in normal milk.

CHAPTER V

MILK AND DAIRY PRODUCTS AS FOOD

For centuries, milk has been recognized as an almost indispensable food for mankind. Its value in the human diet and as a supplementary feed for animals was known for hundreds of years before it came under the scrutiny of the science of chemistry. Until within the past two decades, as the result of the early investigations in nutrition, all foods were looked upon merely as sources of proteins and of energy. In connection with nutritional studies of milk, attention was called to the fact that milk contains all the food constituents required in the human diet and in essentially the proper proportions.

It has been clearly established that the value of milk is based upon more deeply seated fundamental facts than merely the amount of protein and energy it supplies to the body. First of all, milk supplies proteins of exceedingly high quality and of a nature to supplement, especially well, proteins in the human diet from other sources. Milk also supplies liberal amounts of calcium which is often otherwise deficient in the human diet, and third, milk is an excellent source of the vitamins necessary to health.

FOOD REQUIREMENTS

All living organisms require certain elements in order that the life processes may proceed. These elements are secured by the various forms of life in many different states, from those of the most simple to those of most complex nature. The mammal represents the highest form of life. The food requirements of the mammal include the following:

1. Water.
2. Carbohydrates and fat.
3. Protein.
4. Mineral matter.
5. Accessories to growth and health (vitamins).

Water. The body of the mammal consists of about 60 per cent water. All tissues contain water in varying proportions. Water serves as the carrier of food and waste to and from the cells of the body. It holds various constituents in solution and distributes the heat of the body. No animal can live without water. All foods consumed by man and animal contain water. Milk consists of a relatively high percentage of water, but such vegetables as radishes, pumpkins, tomatoes, spinach, and many of the fruits contain nearly as much or even more water than milk. The water content of a few common foods is as follows:

	Water, per cent		Water, per cent
Round steak	65	Peaches	89
Pork	34	Potatoes	78
Salmon	60	Turnips	90
Eggs	65	Tomatoes	94
Bread	35 to 60	Carrots	88
Cheese	37	Lettuce	94
Apples	84	Milk	86 to 88

Carbohydrates and Fat. The body of the average man contains about 1 per cent of carbohydrates and nearly 15 per cent of fat. These constituents which contain carbon, hydrogen, and oxygen are essential for the animal body as a source of heat and energy. The animal body is entirely dependent on its food supply to furnish it with heat and the energy with which it may move about. Just as the steam engine requires coal or oil of a definite amount to produce a given amount of steam which is transformed into power, so the animal body requires fuel, which on oxidation results in the generation of heat and energy. Carbohydrates and fats are the principal sources of heat and energy in the body. Heat may be expressed in terms of the large calorie or the amount of heat required to raise 1,000 grams of water 1°C. (from 3.5 to 4.5°C.). The amount of heat which is supplied to the body from carbohydrates is 4.1 large calories per gram, from fats 9.3 calories per gram. In addition, proteins may supply the animal body with energy, 1 gram supplying 4.1 calories. The average man of the city requires from 2,500 to 3,000 calories per day. A man at rest may utilize but 1,700 calories a day, while a man at hard labor may require from 4,000 to 5,000 calories daily. The carbohydrates and fats may be used by the body as a source of heat and energy, or they may be stored in the body and thus provide the body with stored heat and energy. Fat deposits serve to insulate the body and thus assist in conserving heat and energy in the body.

Source of Energy-producing Foods. The principal sources of foods which furnish the body with a rich supply of energy include foods rich in sugars and starches. Such foods as cane sugar, potatoes, cornmeal, hominy, and bread are rich in carbohydrates and supply large amounts of heat to the body. Foods rich in fat, such as nuts, chocolate, peanut butter, lard, fat pork, and sausage, may supply the body with large amounts of heat, or may be the source of fat stored in the body.

Milk contains a carbohydrate in the form of milk sugar and, in addition, contains fat and protein, thus furnishing to the body when consumed a supply of heat and energy.

Proteins. Science has shown that animals may survive for a long period without carbohydrates or fat, but if certain proteins are not included in their diet, the animals will die shortly. Proteins differ from carbohydrates in their elementary composition in that they contain nitrogen in addition to carbon, hydrogen, and oxygen. Proteins may also contain sulfur and phosphorus, and some of the proteins are known to contain such elements as iron, iodine, copper, manganese, etc. Plants build their protein from the elements of the soil and air, while the proteins of the mammal are constructed from the proteins supplied from plants and other animals. Proteins are required in the body of mammals to build up the worn and new tissues of the body, to develop muscle, nerves, ligaments, skin, blood, lymph, and tendons. In addition, they are required in the bones, hair, nails, hoofs, and feathers of animals. The body of the average man contains about 15 per cent of protein. Man requires from 60 to 100 grams of protein daily along with carbohydrates and fat.

Source of Proteins. Proteins are present in most foods, although the extent to which they occur varies materially, and few foods from plant sources supply them in liberal quantities. In general, the seed of the plant contains relatively higher amounts of protein than the leafy portions. Such foods as peas, beans, lima beans, wheat bread, and rolled oats are the principal sources from which man derives proteins of plant origin. Meats and eggs are especially valuable sources of protein for man. Milk contains several proteins and is exceedingly valuable as a food because of this fact. When milk constituents are concentrated into such products as the various types of cheese, these products become the richest known sources of proteins for man.

Structure of Proteins. The chemical structure of protein has baffled the chemists for a number of years. The chemist has learned, however, that on hydrolysis proteins yield a mixture of amino acids. It is evident therefore, that proteins are made up of various amino acids. Just how the amino acids are linked together in proteins is not clear. It has been shown, however, that proteins of various sources contain widely varying amounts of amino acids. There are known to be 23 amino acids found in proteins, and it is known that not all the amino acids are present in all proteins.

It has been demonstrated, for example, that the protein of corn, which is known as "zein," is deficient in the amino acids lysine and tryptophane, and animals fed corn as the only source of protein made an unsatisfactory growth. The addition of the two amino acids to the diet, however, resulted in growth and normal development. Thus, there is a difference in proteins according to their source. In feeding experiments using rats, it has been demonstrated that certain of the amino acids are essential to body growth, health, reproduction, and various other physiological processes. These amino acids include arginine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophane, valine, histidine, and proline. It has been shown, however, that arginine and histidine are not required by man when on a well-balanced diet. Thus, it may be stated that there are eight essential amino acids at present recognized as needed by man.

The proteins of milk are exceedingly valuable to man and animal, since they contain all the essential amino acids. In addition it can be stated that the amounts of these amino acids in the milk proteins exceed the amounts in proteins from other sources, as eggs, the common meat cuts, and vegetables. These facts have led scientists to conclude that milk proteins are among the most valuable proteins for man.

Minerals or Ash. Though the amount of mineral elements in the body of mammals is relatively small, it is essential that the body be supplied with these constituents. The bones of the skeleton are principally calcium and phosphorus with a small amount of magnesium; therefore, it is evident that a liberal supply of these elements must be furnished in the food for building and maintaining the skeleton. In addition to these, however, the mammal body requires small amounts of other minerals, including sodium, potassium, iron, chlorine, copper, and iodine. These elements are required for various purposes in the body, and not only must the food consumed by the mammal contain these elements, but evidence indicates that the ratio of these elements to one another is important.

Source of Minerals. Minerals are found in most foods available to man and animals. Science has shown, however, that more attention is due the mineral constituents of the diet than has been given in years past. Foods high in protein may carry such mineral elements as sulfur, iron, phosphorus, copper, and magnesium, but these elements are not found associated with all proteins. Meat proteins supply minerals, although in relatively small amounts. Furthermore, much of the mineral content is in the inedible portions, for example, in the bones. The elements required by the body in largest amounts, as indicated in the previous paragraph, are calcium and phosphorus. These elements are best supplied to man through the leafy portions of vegetables, from fruits and milk. In addition, fruits and vegetables are an excellent source of iron, potassium, and iodine.

Milk and Milk Products as a Source of Minerals. As indicated, milk is an excellent source of certain minerals required by the body. Attention may be directed to the ratio of calcium and potassium to magnesium and sodium in milk. This ratio as it occurs in milk resembles very closely the ratio of these same elements in the body of man. Milk contains all the essential mineral elements required by man, and milk with its products has been pronounced by nutritional experts as an excellent source particularly of calcium. Too much emphasis cannot be placed on this fact, since calcium is so essential in building the body skeleton as well as affecting muscle action including the heart muscle, and since it is not obtainable in a large variety of foods.

Cheese has been shown to be a particularly important source of calcium in the diet of man. Fruits and vegetables eaten in liberal quantities supply calcium to the body, but the addition of milk to the diet insures the body an abundance of this mineral in quantities greater than will be found in any of the common foods.

The calcium content of milk is three times that of wheat, greatly exceeds that of corn, and is four times as great as that of human milk.

Milk is frequently criticized as being low in iron. It is true that milk is low in iron, too low, in fact, to meet the needs of the body if taken as the sole diet, but the iron of milk is readily available to the body. The newborn is supplied with a store of iron sufficient to care for its needs until past the stage of depending upon an exclusive milk diet, hence the deficiency in this element is not considered serious. Iron is readily secured through other sources, such as the leafy vegetables and fruits. Eggs are also a very good source of iron.

Food Accessories. In addition to the food constituents required by mammals, namely carbohydrates, fats, proteins, and minerals, certain constituents are also essential for the growth, general health, and reproduction of mammals. These essential substances for life are termed "vitamins." McCollum and Davis, and Osborne and Mendel, working independently with purified foods, found that milk fat or ether extracts of milk fat or egg yolk contained a substance essential for growth. This substance became known as "vitamin A," or "fat-soluble A." The work of these men opened a new field in the study of nutrition. Within a few years after the discovery of vitamin A, other workers announced the finding of new and different vitamins. The subject has become a specialized field, and it should be clear to the reader that facts given here may be altered before this text reaches the printer. This statement is made because of the complexity of the entire subject and to emphasize how rapidly new facts are being released. Those working in the field of nutrition are still undecided on many points about vitamins. Early workers knew little about their nature. They were able to prove their existence but could not specify the composition of the vitamins. Up to the present time, over 25 vitamins have been reported, although some of these are not recognized by all authorities.

It is now possible to identify definitely a number of the more important vitamins. Their composition and chemical structure are known. They can be and are being prepared synthetically in the laboratory of the chemist for the druggist's shelf and for use in the home or by the food processor.

Vitamin A. This vitamin is essential in the diet for the proper growth of the mammal. If the vitamin is lacking in the diet, the animal or man is susceptible to infection of the lungs, eyes, ears, sinus, and the base of the tongue. Xerophthalmia, a disease of the eyes, is so commonly associated with a lack of vitamin A that this vitamin is frequently referred to as the "antixerophthalmia" vitamin. It is this vitamin which is essential in maintaining a normal level of visual purple in the eye. The inability of an individual to adapt his vision to objects when passing from a well-lighted to a dark room is one of the first indications of a lack of vitamin A. Although the vitamin was first observed as present in milk fat and egg yolk, it is known to be present in even greater amounts in cod-liver oil. Such foods as the green leaves of plants are an excellent source of vitamin A for growing animals. The vitamin is secured in liberal quantities by man from such foods as milk, butter, cheese, and other dairy products, and from such vegetables as spinach, carrots, and tomatoes. It is secured to a moderate degree from many other vegetables, meats, and fruits. So far as known, vitamin A is a plant product and for this reason the amount in milk is dependent upon the supply received with the feed. Milk has the greatest vitamin A content when the animals are receiving fresh pasture grass or carefully cured legume hay.

Thiamin (*Vitamin* B_1). The absence of this vitamin stunts the growth of the animal and results in such diseases as beriberi in man and polyneuritis in birds. It has been shown that thiamin is essential in the oxidation of pyruvic acid from carbohydrate foods and thus has an important relation to the complete utilization of carbohydrates in the body. A lack of the vitamin is associated with a loss of appetite, slow heart rate, nervousness, and constipation as well as the accumulation of a toxic substance, pyruvic acid, in the body tissues. Thiamin is found more generously distributed in the common food materials than is vitamin A. It is found in milk and its products, the seeds of many plants, particularly in the embryo portion, in many fruits and vegetables.

Its principal source for man is the cereals made of the whole seed, whole-wheat flour, egg yolks, and milk. The vitamin is also present in yeast. The thiamin content of milk is at least partly dependent upon the amount supplied by the feed of the cow. There is evidence, however, that this vitamin is also synthesized by bacteria in the rumen of the cow, and from this source a portion of that found in the milk may be derived.

Riboflavin (Vitamin B_2 or G). This vitamin is essential for growth and the health of the skin. Like thiamin, it acts as an enzyme in influencing the oxidation of pyruvic acid. It is also thought to influence the functioning of the eyes. It is found in all dairy products. The presence of riboflavin was first noted in milk and was termed "lactoflavin," the yellowish-green substance which is responsible for the characteristic color of whey. Like vitamin A, the amount of riboflavin found in milk varies to some extent with the feed received by the cow. The vitamin is to be found in a variety of other foods including liver, glandular meats, veal, lamb, pork, beef, eggs, green and leafy vegetables, and legumes. It is estimated that 1 to 2 milligrams of riboflavin are required daily by an adult. One quart of milk will supply 2 to 2.5 milligrams. Cheddar cheese has been shown to be an excellent source of riboflavin.

Nicotinic Acid (Niacin). This is one of the B-complex vitamins sometimes called "vitamin PP" or the pellegra-preventative vitamin. Although the chemist prefers the term "nicotinic acid," there has been some demand for the term "niacin" which it is thought would not be suggestive of nicotine. The vitamin is essential for the prevention of human pellagra, a nutritional disease known to occur in certain sections of the United States. It is essential to the health of the skin and to the proper functioning of the gastro-intestinal tract and the nervous system. The vitamin is to be found in milk, glandular meats, veal, pork, lamb, beef, eggs, fish, and legumes. The adult requirement is estimated at 10 to 15 milligrams daily. The growing child needs from 6 to 8 milligrams daily until it reaches its teens, when the intake should be increased to as high as 20 milligrams daily. One quart of milk will supply approximately 0.96 milligrams of niacin to the diet

Other Vitamins of the B-Complex. Workers in the field of nutrition have been able to show that there are a number of other nutritional factors that are very closely related. Much of the present knowledge is based upon results obtained on small animals and at this writing has not been applied to human nutrition experimentally. An antiparalytic factor, B_4, and an antidermatitis factor, B_6, for rats have been recognized, the latter identified as pyridoxine and an antidermatitis factor for chicks identified as pantothenic acid. There is some evidence that pantothenic acid is essential to human nutrition and that its function is closely related to riboflavin. Intimately linked with pantothenic acid are still other vitamins of the B-complex, inositol, which has been associated with adrenal hemorrhages, and para-aminobenzoic acid, a vitamin that it is claimed to be responsible for the restoration of color to graying hair. It is now established that the miraculous cure of pernicious anemia by the feeding of whole liver is due to the presence of B_{12} known for many years as "nutrient X." The importance of these and others of the vitamin B-complex from the standpoint of human nutrition will doubtless become better known within a few years.

Ascorbic Acid (*Vitamin C*). When ascorbic acid is lacking in the diet of an animal, such as the guinea pig, it will grow for about 2 weeks, then lose weight and die of scurvy. Not all animals are affected in this manner, but none are immune. The vitamin is sometimes referred to as the "antiscorbutic vitamin." A lack of this vitamin is responsible for scurvy. Vitamin C is essential for cellular respiration, blood regeneration, the maintenance of the strength of blood vessels, the development of teeth and bone, and the formation of connective tissue. It is available to man through fresh vegetables, fruits, and milk. The vitamin is destroyed by the application of heat in the presence of air to the extent commonly used in the pasteurization of milk, and for this reason when pasteurized milk or milk products are used in the diet, ascorbic acid should be supplied in the ration through other sources, such as oranges or fresh tomatoes. The ascorbic-acid content of milk is apparently increased when cows are permitted to graze on good pasture; however, the evidence available to substantiate this statement is somewhat conflicting.

Vitamin D. This vitamin is also closely associated with vitamin A and influences the growth of the animal in much the same way. Vitamin D, however, has the special property of preventing rickets and favoring the normal deposition of calcium and phosphorus salts in the growing bones. This vitamin is especially abundant in cod-liver oil but does not appear to be so widely distributed as the other vitamins. Although present in milk, the amount is relatively small. It has been established that sunlight may take the place of vitamin D as an antirachitic factor.

In recent years, the vitamin D content of milk has been increased either by the feeding of irradiated yeast to the cow, direct exposure of milk to ultra-violet light, or the addition to milk of concentrates exceedingly rich in the antirachitic factor. This is a palatable and readily accepted source of this vitamin.

There are at least 10 sterol derivatives that are known to show vitamin D activity. Among these may be listed activated ergosterol and 7-dehydrocholesterol.

Vitamin E (*alpha-tocopherol*). A vitamin designated as vitamin E or alpha-tocopherol is known to affect the fertility of animals, and thus becomes a factor influencing reproduction. Vitamin E is apparently present in fatty foods, including milk fat, the wheat germ, whole wheat, lettuce, meat, rolled oats, and dried alfalfa.

Vitamin K. Another vitamin now recognized is vitamin K, which has been termed the "Koagulation" vitamin. The vitamin appears to be essential for the normal coagulation of blood. Among the sources of this vitamin may be listed leafy vegetables, cereals, pork-liver fat, rice bran, soybean oil, and milk and its products.

REQUIREMENTS OF A SUITABLE FOOD

The mere presence in a food of the food constituents discussed does not render a food entirely satisfactory to man. Certain other requirements which should be considered in the selection of food materials may be set forth as follows:

1. Man requires that a food be palatable.
2. Man requires a clean, wholesome food.
3. Man requires foods which are digestible
4. Man requires economical foods.

Palatability of Foods. One of the first requirements of a food is that it be palatable. A food should be relished and enjoyed by a given individual if it is to be included on his menu. Milk is liked by most people. Its flavor is one which is enjoyed. In addition, milk is easily flavored with many flavoring materials and can be made palatable very readily for those who do not care for it in its natural state.

Cleanliness of Food. Food must be clean if it is to appeal to the average person. A clean, wholesome food attracts the attention and creates a desire. Milk for direct consumption can be produced under very sanitary conditions and thus meets this requirement.

Digestibility of Foods. Though it is essential that the various food constituents be present in a given food, it is also important that these constituents be present in such a form as to be readily utilized by the body. The proportion of each food constituent of a given food which is utilized by the body is frequently expressed in terms of percentage. An enormous amount of work has been conducted in determining the value of the various foods available for man and animals.

The percentage of the various food constituents of milk which are digestible is high. In fact, it is possible for certain individuals to utilize as much as 98 per cent of the protein of milk, and 99 per cent of the carbohydrates and fat. The digestibility of proteins is given by various authorities as between 80 and 100 per cent. Some give the digestibility of animal proteins and milk as 90 to 100 per cent; proteins from cereals, fruits, or vegetables as 80 to 90 per cent; and proteins from legumes as 80 per cent or lower. In addition to the digestibility of proteins, attention should be directed to the differences in the composition of proteins from various sources. All proteins do not contain the essential amino acids; however, milk proteins are extremely valuable from the standpoint of their amino-acid content.

Economy of Milk as Food. The particular foods that make up the diet of a family depend upon a number of factors, the most important of which are food habits, availability, palatability, desirability from the standpoint of health, and economy in cost. Interesting and valuable information may be obtained concerning the economy of milk by comparing the relative cost of food constituents in milk and dairy products with other common foods. The difficulty that at once arises, however, is that food values cannot be expressed in any one term. This is particularly true of milk. Certain foods are purchased primarily for a certain class of constituents. Thus, bread is an excellent and cheap source of carbohydrates; lard, of fat, and certain meats, of protein. These foods do not furnish any considerable quantity of other constituents. In contrast, milk contains constituents of all classes needed by the body. It manifestly is not fair to compare milk with bread as a source of energy, with lard as a source of fat, or with lean meat as a source of protein.

Milk as a Source of Protein. The value of a given food as a source of protein cannot be judged entirely on the total protein content. The protein foods that supply the body with a variety of the amino acids, which go into the building of proteins, are known to be of more value than those which supply relatively few of these amino acids. Not only is it important that a large variety of the amino acids be present in a given protein, but it is known that certain of the amino acids may be classified as "indispensable." These essential amino acids are valine, leucine, isoleucine, phenylalanine, tryptophane, threonine, methionine, arginine, histidine, and lysine. It has been demonstrated that proteins from animal origin possess a greater proportion of these essential amino acids than proteins from a vegetable source. Milk is known to contain all the nutritionally essential amino acids in fairly high amounts. In addition the milk proteins, casein and albumin, have associated with them certain biologically important minerals, such as calcium and phosphorus, as well as certain vitamins which seldom occur in proteins from other sources. These are facts which emphasize the importance of including milk proteins in the diet.

It is possible to classify foods from the standpoint of protein content disregarding the quality. Foods such as cheese, lean meat, lean fish, dried beans, peas, lentils, and peanuts contain a high concentration, 20 per cent or more, of protein. Eggs, most nuts, and a majority of the cereals contain from 10 to 20 per cent of protein. Finally, a group of foods may be listed that contain less than 10 per cent of protein. These include milk, bread, and fresh vegetables. Even though milk falls into that group of foods that contain protein in a less concentrated form, it is regarded as an excellent source of protein. One-half of an adult's protein requirement, approximately 34 grams, can be supplied from 1 quart of milk. A pound loaf of bread (made with milk, containing 6 per cent of non-fat milk solids) will supply about the same amount of protein as 1 quart of milk.

The amount of a given food required to equal in protein content

1 quart of 4 per cent milk and in total energy is reported in Illinois *Circular* 235 The data in Table VIII of this publication show that 6.3 ounces of sirloin steak contain as much protein as 1 quart of 4 per cent milk. To equal the energy supplied by milk, however, it will require 11 ounces of steak. Comparisons are not given in terms of money value on account of the fluctuations in prices from one locality to another and from year to year. By using local prices, a fair comparison may be readily obtained.

Table VII. Weights of Foods Necessary to Yield an Amount of Protein and Energy Equivalent to 1 Quart of 4 Per Cent Milk

	Amount of protein, ounces	In total energy, ounces
Sirloin steak	6.3	11.0
Round steak	5.4	16.2
Pork chops	7.8	8.6
Ham, lean smoked	6.0	9.8
Fowl	7.6	14.0
Eggs	4.4	8.9
Halibut steak	6.8	23.0
Mackerel, salt	6.4	10.5
Salmon, dressed	7.6	18.2
Whitefish	9.9	33.6
Full cream cheese	3.1	5.4
Cottage cheese	5.0	21.2
Dry beans	4.7	6.7
Baked beans	15.2	18.0
Dry peas	4.2	6.5
Canned peas	29.0	42.0
Rolled oats	6.3	5.8
Peanut butter	3.6	4.2

For example, if ham costs 40 cents per pound and milk 14 cents per quart, 6 ounces of ham costing 15 cents will supply the same amount of protein as 14 cents will buy in the form of milk. To obtain an equivalent amount of energy in ham, however, an expenditure of 34 cents will be required. Milk is usually a relatively cheap source of protein compared with other foods supplying proteins from animal sources such as eggs, meat, and fish.

Milk as a Source of Energy. All of the solids of milk except the ash serve the body as sources of energy. Fat has a caloric value per unit about double that of protein or sugar. In average milk the caloric value of the fat is nearly equal to that of the sugar and protein together. A comparison can be readily made between the energy or caloric value of milk and other foods as shown below.

ONE PINT OF MILK—337 CALORIES—AND ITS ENERGY EQUIVALENT IN OTHER FOOD MATERIALS

Food materials	Weight, ounces	Food materials	Weight, ounces
Skimmed milk	32.4	Bananas	18.7
Cream	6.1	Prunes	4.6
Cabbage	45.0	Bread	4.6
Onions	27.0	Rolled oats	3.0
Sugar	3.0	Rice	3.4
Honey	3.6	Bacon	1.9
Potatoes	17.7	Round steak	6.2
Grapefruit	35.0	Eggs	9.0
Peanuts	2.9	Butter	1.6
Apples	25.3	Cheese	2.7

It appears from the above calculations that 1 pint of milk containing 337 calories is equivalent to 17.7 ounces of potatoes, 25.3 ounces of apples, 4.6 ounces of bread, 9 ounces of eggs, and 3 ounces of rolled oats.

A common method which has been used in comparing foods is to determine the number of calories that can be purchased for a given amount in a food at the prevailing market price. On this basis, milk is not found to be the cheapest source of energy. This position is usually held by the cereal products including oatmeal, corn meal, and bread. Milk, however, supplies calories more cheaply than many other foods, especially meats and eggs, fruits, and usually the vegetables.

Relation of Richness of Milk to Food Value. On account of the variations in composition due to the breed of animals, milk as offered for sale may contain anywhere from 3.00 to 5.50 per cent of fat. As pointed out elsewhere, a variation in fat percentage also means a variation in the proportion of other constituents, although not in the same proportions. The question of the food value of milk as affected by the fat percentage often arises. A family may be offered milk for 12 cents a quart from one source and for 16 cents from another, the only apparent difference being in the fat percentage. Is the higher price justified?

A definite answer to such questions is difficult, but help in solving the problem may be had from the data given in Table VIII. Information should first be secured regarding the average fat content of the milk from the two sources. Perhaps the milk offered at 12 cents would contain, approximately, 4.00 per cent fat and that offered at 16 cents, 5.00 per cent fat.

TABLE VIII. RELATION OF RICHNESS OF MILK TO FOOD VALUE[1]

Percentage	Food substance, per quart, grams	Calories, per quart	Total calories, per quart
3 *per cent fat:*			
Fat, 3.00	29.3	263.8	
Protein, 2.64	25.9	193.5	
Sugar, 4.60	44.9	179.0	546.9
4 *per cent fat:*			
Fat, 4.00	39.0	351.2	
Protein, 3.04	29.7	118.9	
Sugar, 4.88	47.6	190.5	660.6
5 *per cent fat:*			
Fat, 5.00	49.3	443.9	
Protein, 3.62	35.4	141.5	
Sugar, 4.92	48.1	192.4	777.8
6 *per cent fat:*			
Fat, 6.00	58.0	522.3	
Protein, 3.92	39.0	156.0	
Sugar, 4.88	47.7	190.6	868.9

[1] Adapted from *Circ.* 235, Ill. Exp. Sta.

Milk containing 4 per cent fat, as shown in Table VIII, contains 29.7 grams of protein per quart while 5 per cent milk contains 35.4 grams. Solving this simple problem in proportion will show that the 5 per cent milk on a protein basis would be worth 14.3 cents per quart. As a source of energy, the proportion would be between 660.6 and 777.8 and would indicate a value of 14 cents for the 5 per cent milk in comparison with 12 cents for the 4 per cent product. If the richer milk sells for 16 cents, compared to 12 for the 4 per cent milk, the price must be partly justified in other ways than by food value; for example, by better sanitary conditions or better service. The tendency on the part of the public is to undervalue the richer milk. In the retail milk trade, it is difficult to obtain the 2 extra cents per quart for 5 per cent milk which is justified by the higher food value.

Milk for the Growing Child. Milk is generally recognized as an excellent food for the growing child. Since milk contains all of the food constituents, namely, carbohydrates, fat, proteins, and mineral matter in about the proportion which the growing child requires, it has been frequently referred to as a "perfect" food. In addition, milk is rich in mineral salts, particularly calcium, which is so vital in the development of the growing skeleton of the child. Doctors and dentists recommend milk in the diet of children and not infrequently nutrition experts recommend that the growing child should have included in its diet 1 quart of milk daily. In addition to the food constituents, milk is known to contain all of the vitamins essential for growth, health, and reproduction.

These are not the only reasons, however, for including milk in the diet of the child, particularly the infant. The constituents of milk are highly digestible, palatable, and require little preparation. The infant requires milk either from its mother or from other sources, but frequently in certain cases it is essential that milk be slightly modified for infant feeding.

The degree of softness of the curd resulting from coagulation is also important in infant feeding. It has been found that some cows produce milk which gives a softer curd than others, and that the softer curd is more easily digested than the firmer curd. Consequently, there has been a special selection of "soft-curd" milk for the use of infants or invalids or the treatment of ordinary milk in such a way that a softer curd results. Homogenization, high-temperature treatment, sonic vibrations, the addition of enzymes, and base-exchange processes have been used to provide milk yielding a softer curd.

Milk for the Adult. Milk is an excellent food for the adult as well as for the growing child. It should be clear, however, that in the case of the adult it is not possible to secure as large a proportion of the total nutrients required as in the case of the infant or the growing child. Milk contains too much water to serve as the major portion of an adult's diet. It would require 8 to 11 pounds of milk daily to furnish the nutrients required by an adult. In addition, milk is too high in protein for the average adult, and the solid material is too concentrated. The digestive system requires some foods which are relatively high in fiber for proper development even in the growing child. A mixed diet is to be recommended. In the diet, however, milk should be included for both the growing child and the adult.

Pasteurization, Effect on the Nutritive Value of Milk. The effect of pasteurization on the nutritive value of milk has been a subject of much discussion and frequently raised when state legislative bodies consider the question of compulsory pasteurization of all milk distributed to the public. On the basis of the best information available, it may be stated that the heat-treatment of milk during pasteurization results in a partial destruction, probably about 20 per cent of the activity of the vitamin C and thiamin content of milk. The heating of milk to temperatures employed in pasteurization may result in a slight precipitation of some calcium and phosphorus, but the amount so altered is negligible. This is particularly true in view of the fact that milk is rich in these elements.

The contention that pasteurization may materially affect the digestibility of milk and that the salts are rendered less soluble cannot be substantiated according to our present knowledge.

FOOD VALUE OF OTHER DAIRY PRODUCTS

In the foregoing discussion pertaining to the food value of milk, little has been stated in reference to the food value of milk products such as skim milk, cheese, butter, and concentrated milks, including condensed and dry milk.

Butter. Butter differs from other dairy products in that it is a highly concentrated fat food and contains very little of the other milk constituents. Butter contains between 81 and 84 per cent of milk fat, a small amount of salt, and less than 1 per cent of protein. It is evident, therefore, that butter is chiefly a source of energy, supplying, when of average composition, 3,410 calories per pound. In addition, however, butter is an excellent source of vitamin A and is frequently mentioned by experts in nutrition as the chief source of this vitamin in the diet of the average

American. A survey of the vitamin A content of creamery butter made in the United States has shown the average potency to be approximately 15,000 International units per pound. It was revealed that 34 per cent of the creamery butter produced in America is "winter" butter and contains an average vitamin A potency of 10,500 or 11,200 International units per pound depending on the method of calculation. "Summer butter" produced when cows are on pasture, and representing 65 per cent of the butter made, has an average vitamin A potency of 17,000 to 18,000 International units. A small amount of vitamins D and E are present in butter; however, it is lacking in vitamins B_1 and C. Butter is not generally an especially cheap source of calorics. Its palatability and vitamin A content, however, fully justify its wide use.

There is growing evidence that, as in the case of proteins, there is a difference in the nutritive properties of natural fats. Feeding experiments with calves at the University of Minnesota have shown that milk fat is superior to many other fats for calves. This did not prove true, however, when such fats as soybean oil or cottonseed oil were hydrogenated. Other work at Minnesota and Wisconsin would lead one to believe that there may be certain of the fat acids that are more essential than others. In no other fat in nature is there to be found such an assortment of fat acids as are found in milk fat. This may be a very important fact from the standpoint of nutrition.

Cheese. Most of the market varieties of cheese manufactured consist of a concentration of the milk solids of milk, chiefly casein, and milk fat. The food value of cheese depends on the proportion of water retained with these solids. Cheese may largely replace meat in the diet. It is the cheapest source of animal protein adapted for human food. In addition, cheese is an excellent source of calcium, phosphorus, and sulfur and is fairly high in iron.

Ice Cream. The food value of ice cream varies with its composition; however, all the constituents of milk are present in a concentrated form. Where milk contains between 86 and 89 per cent of water, ice cream contains between 60 and 68 per cent of water. In addition, ice cream contains added sugar. To ice cream may be added such materials as eggs, gelatin, fruits, nuts, chocolate, and bakery products, all of which add to its food value. It is evident, therefore, that ice cream contains a rich supply of the food nutrients.

Concentrated Milks. Dry milk and condensed milk contain all the food constituents of milk in a highly concentrated form. The food value of these products depends on the extent to which they are concentrated. If water equal to that removed be added to these products, the result is a milk with essentially the same constituents and food value as the original product.

Skim Milk. Skim milk contains all the solids of milk excepting the milk fat. The water and milk solids-not-fat content of skim milk are present in very nearly the same proportion as they occur in milk. Since skim milk contains but a fraction of a per cent of milk fat, the vitamin A, D, and E content is low. The vitamins which are water-soluble, including the B-complex and ascorbic acid (vitamin C), will be found present in skim milk. Skim milk is known to be an excellent source of animal protein of high quality, however, and of the minerals, calcium and phosphorus. In addition, skim milk contains about the same proportion of lactose as is found in whole milk. As a feed for young growing animals, therefore, skim milk is excellent. Not infrequently skim milk is considered an inferior food for man, primarily because of its cheapness. So far as its food value is concerned, it is quite as valuable as whole milk from which it is derived, with the exception of its lack of milk fat. It is, therefore, an excellent and inexpensive source of milk protein and mineral elements for man. When included in the diet of growing children, care should be taken to insure the child an adequate supply of vitamin A from other sources, such as butter.

Buttermilk. The composition and food value of buttermilk are comparable with skim milk with the exception that it may contain slightly more milk fat. Owing to the decomposition of lactose by bacteria, buttermilk frequently contains from 0.2 to nearly 1 per cent of lactic acid. The presence of lactic acid in buttermilk is not harmful and may be beneficial.

Fermented Milks. The food value of fermented milks is equivalent to that of the whole or skim milk from which they were prepared. These products depend upon the action of microörganisms for their desirable characteristics. The principal product formed in the fermentation is lactic acid. Most of the fermented milks are considered to be especially healthful.

Some of them contribute desirable types of bacteria which establish themselves in the lower intestines. They compete with the undesirable putrefactive bacteria which ordinarily predominate along the intestinal tract and which produce toxic products. When lactose is available either from the milk or by direct addition in the diet, the desirable types of bacteria gain the ascendancy and dominate the fermentation, which becomes an acid, rather than a putrefactive, type of fermentation.

CHAPTER VI

MICROÖRGANISMS

THEIR NATURE AND GROWTH REQUIREMENTS

The dairy industry is vitally concerned with minute, living cells which are called "microörganisms." Nearly all of the changes which take place in the taste, odor, or appearance of milk, after it comes from the cow are the result of the activities of these organisms. Such common phenomena as the souring of milk or the formation of characteristic flavors in cheese are to be attributed to their action. The methods employed in the care or handling of milk or its products are directed largely toward the control of these microörganisms. An understanding of the changes which take place in milk or other dairy products is impossible without some knowledge of these organisms and the conditions which affect their growth.

The microörganisms which are most important in dairying are the bacteria, yeasts, and molds. All of these are members of the plant kingdom, and belong among the fungi; that is, they are plants without chlorophyll, the green coloring matter of higher plants.

Bacteria. Bacteria are microscopic, unicellular fungi which occur principally in the form of spherical, cylindrical, or spiral cells, and which reproduce by transverse fission. In dairy products, the spherical and cylindrical forms are predominant.

Distribution. Bacteria are found nearly everywhere in nature. They are prevalent wherever organic matter is available as a source of nourishment. They are found in tremendous numbers in the soil, sewage, decaying plant or animal substances, etc. Some are present in the air which one breathes, the water which one drinks, and on the clothes which one wears.

Size. Bacteria are so minute that they are visible only with the aid of a microscope. The unit of measurement is a micron, which is equal to 0.001 millimeter or 1/25,000 inch. The spherical type seldom has a diameter greater than 1 micron.

There is greater variation in the size of the cylindrical types. There are some which measure 0.2 × 0.5 micron while others may be 40 to 60 microns in length and 3 to 6 microns in width. The majority, however, are about 1 × 2 microns in dimension. It is estimated that 50 of these would be required to equal the thickness of ordinary writing paper.

It is not difficult to understand that large numbers of these cells may be present in a substance like milk without occupying an appreciable space. A milliliter (cubic centimeter) of milk may contain millions and even billions of bacteria. It has been estimated that approximately 16,000,000,000 average-sized bacteria would be required to balance a weight of 1 milligram (0.001 gram).

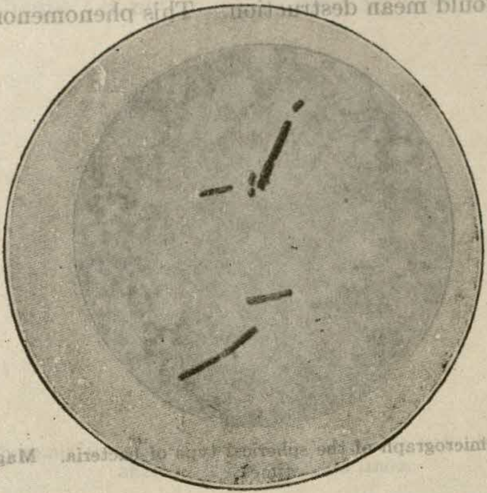


FIG. 14. Photomicrograph showing rod forms of bacteria. Magnified 1,475 times.

Cell Structure. The bacteria are unicellular, which means that they are individual, single cells, each capable of pursuing its physiological processes independently. The cell consists of a rather well-defined mass of clear, colorless protoplasm without the demonstrable nucleus which is found commonly in most living cells. The individual cells may be united into pairs, chains, or clusters, but each cell retains its independent functions. Such groupings are to be attributed largely to physical forces. In certain forms, the surface of the cell becomes covered with a sticky, gum-like film which is called a "capsule." It will be explained later how such a condition may be responsible for a particular physical change in milk, known as "ropiness."

There are also some bacteria which, in the presence of inimical substances, in the absence of essential foods, or under unsuitable physical conditions, may concentrate their cell contents into a thick-walled structure designated as a "spore." This spore is very resistant to desiccation and heat. It makes possible the preservation of the bacterial life under circumstances which ordinarily would mean destruction. This phenomenon has some important practical significance, as will be seen in subsequent pages, particularly in relation to pasteurization.

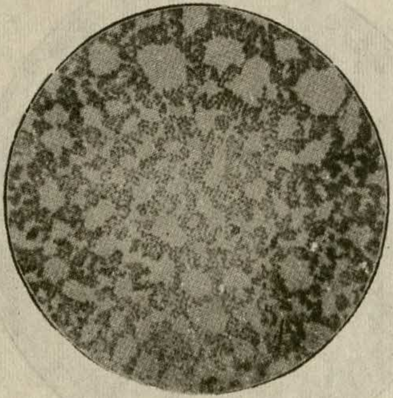


Fig. 15. Photomicrograph of the spherical type of bacteria. Magnified 1,475 times.

Motility. When viewed under the microscope, all bacteria, when in liquids, show a vibratory motion which is known as the "Brownian movement." Some types, however, show a true motility, that is, the ability to move from place to place independently. They are able to swim about freely with the aid of hair-like projections or cilia which are termed "flagella." This arrangement allows for a change in position in the search for suitable food supplies or a favorable physical environment.

Reproduction. There are apparently no sexes in bacteria. The cell reproduces itself merely by a division across the center, thus forming two cells from the original one. This multiplication, by division, accounts for the extremely rapid reproduction of which the bacteria are capable. Soon after the division occurs, each individual assumes approximately the size and shape of the parent cell. Maturity is almost simultaneous with the separation. Thereafter, each cell may divide again, independently. Thus the next generation will consist of four cells. This process continues in the form of a geometrical, rather than an arithmetical, progression. Under favorable conditions, a new generation may be produced in a period of half an hour. Consequently, if the reproduction of a single cell were to continue at this rate for 24 hours, the progeny of this original mother cell would number several millions. If nothing were done to check such development, in the course of a few days there would be formed a mass of bacteria greater than the earth itself. Obviously, such a result is not possible, because of natural conditions which check this development before it reaches such proportions. Nevertheless, the rapidity with which bacteria may multiply in a favorable medium such as milk becomes a matter of concern of the greatest importance. This will be discussed more in detail in the following pages.

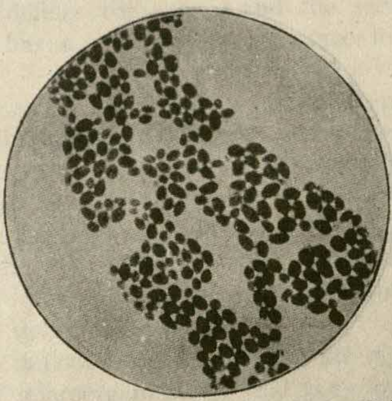


FIG. 16. Photomicrograph of yeast cells. This shows their characteristic oval shape. Magnified 1,475 times.

Yeasts. Yeasts are also microscopic, unicellular, non-chlorophyll-bearing plants but usually are somewhat larger than bacteria and with the cell constituents more highly organized. A definite nucleus may be demonstrated. The method of reproduction is entirely different, however. It may take place through the process of budding in which a portion of the protoplasm forms a slight protuberance on the mother cell and gradually develops into maturity whence it becomes an independent cell, or by the formation within the mother cell of reproductive spores each of which may give rise to a new yeast cell. The yeasts are not so important as bacteria in dairying but do enter into some of the common fermentations and will be mentioned in later discussions.

Molds. The term "mold" is used, popularly, to designate a considerable number of lower fungi, which are much more complex than bacteria and which more nearly resemble the higher plants. Molds are multicellular forms, the individual cells of which are not visible to the naked eye. At maturity, however, they may be observed readily as a mass of branching, radiating, or interwoven threads, called the "mycelium." Each individual thread is known as a hypha.

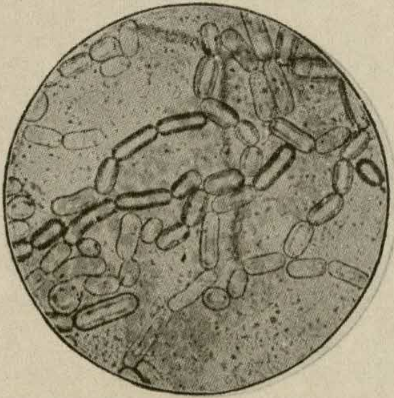


FIG. 17. Photomicrograph of a mold (*Oospora lactis*) commonly found in milk. The oidia, as the spores of this particular mold are designated, are pinched off at the ends of the various branches. The photograph shows many of these oval or cylindrical oidia. Magnified 735 times.

The most common type of reproduction is by means of fruiting bodies which often are brightly colored, and which produce myriads of oidia, or spores, which are disseminated widely. Each of these spores is capable of establishing a new vegetative phase of the mold's life cycle under favorable conditions. Other asexual and sexual methods of reproduction also appear. The group is so complex that it is not practical to discuss it in detail in this text. The molds are of considerable importance in cheese making and are responsible for some defects of butter and other products. These considerations will be introduced elsewhere.

The Naming of Microörganisms. Anyone who reads the technical literature on dairying often will be confronted with the scientific names used to designate the particular species, genus, etc., to which a microörganism belongs. It is not possible to discuss in detail the actual classifications of bacteria, yeast, and molds nor to mention many of the genera or species. The names are derived from many sources and languages, but according to custom and international agreement are given a Latin form and termination. One ordinarily finds an organism designated in the literature by a species name, for example, *Streptococcus lactis* (the common milk-souring type of bacteria), where the first part defines the genus, and the second the species. Each portion has a particular significance in the system of classification.

Some of the genus names of bacteria which may appear commonly in the literature are: *Streptococcus, Micrococcus, Sarcina, Bacillus, Bacterium, Pseudomonas, Lactobacillus, Escherichia, Aerobacter, Spirillum,* etc. Genera of yeasts and related forms may be encountered such as *Saccharomyces, Torula, Mycoderma,* etc. Among the more common genera of the molds will be noted *Penicillium, Oospora, Aspergillus, Mucor, Monilia, Alternaria, Fusarium,* and many others.

This merely indicates that there is an attempt to systematize the naming of microörganisms so that they may be catalogued in convenient, orderly classifications useful to all scientific workers of the world. Each microörganism is given a definite place in this scheme of classification depending upon its special characteristics which differentiate it from all others.

THE GROWTH OF MICROÖRGANISMS

The alterations, in the physical or chemical properties of milk or its products, which are to be attributed to microörganisms, do not occur because of the mere presence of the organisms but result from the activities of the individual cells during the period of their development and reproduction, or from substances produced during such activity. Wherever microörganisms have had an opportunity to grow in a nutrient material, a modification of that substrate, primarily of a chemical nature, must be expected. Simultaneously with the change in chemical constitution, a transformation in the physical properties of the environalso may retard development although this condition seldom occurs in food products.

Yeasts and molds usually grow best on acid media and often initiate their growth after the acidity has become concentrated sufficiently to check bacterial growth. It may be observed that a sour milk or cream will show a heavier growth of mold on its surface than will a sweet product of the same age.

Preservatives. Microörganisms are susceptible to the action of certain chemicals which either check growth or destroy the organisms outright. There are many substances of this sort, which are usually termed "preservatives," "antiseptics," "disinfectants," "germicides," etc. The preservation of composite milk or cream samples by the addition of bichloride of mercury (corrosive sublimate) is an example of this action. This substance kills the microörganisms. Consequently, no souring or decomposition takes place in the sample because there is no growth of the bacteria ordinarily responsible for spoilage. Formalin, boric acid, borax, benzoic acid, salicylic acid, hydrogen peroxide, and other chemicals have been used at one time or another for the purpose of prolonging the keeping quality of milk sold for human consumption. This practice is reprehensible as well as unlawful. The use of various chlorine preparations for the sanitization or "sterilization" of dairy equipment, milk bottles, etc., is a legitimate application of the principle of chemical preservation or "sterilization." In this case, there is no direct addition of the chemicals to milk. Furthermore, chlorine solutions will not destroy the microörganisms in milk unless they are present in such large quantities that the milk itself is changed so much in flavor or appearance that it would not be accepted as food.

Light. The majority of microörganisms grow best in the dark. Light is more or less harmful. Bright light, natural or artificial, has a tendency to check or destroy them. Direct sunlight, unobstructed by ordinary glass, is rapidly destructive. The ultra-violet rays in this connection are the most lethal. They have been utilized for the attempted sterilization of milk but the results have not been particularly successful because some of the amino acids of milk apparently absorb the rays before they can exert a destructive effect upon the microörganisms. Dairy products are seldom kept in the bright light because it is known that light accelerates chemical changes, which are detrimental to the product. Consequently, light is not a very practical agent for checking the growth of microörganisms in milk.

Electricity. A direct or alternating current of electricity in itself does not appear to have a destructive effect upon microörganisms. Methods for pasteurizing milk by electricity are in use at the present time but they depend principally upon the increase in temperature to exert the destructive effect. The resistance offered by milk to the passage of an electric current is sufficient to raise the temperature to a point where bacteria are destroyed. The electricity may also cause the production of chemical compounds which, in turn, may exert a restraining or germicidal effect.

Thunder Storms and the Souring of Milk. A familiar myth has been handed down from generation to generation that a thunder storm sours milk. Supposedly, the thunder and lightning exerted some mysterious power to bring about this change. Fortunately, there is no truth in the myth based upon the action of the thunder or the lightning themselves. Otherwise, many milk dealers in the large cities would be bankrupt. Generally at the time a thunder storm occurs, and some time before, the temperature is unusually high. If milk or cream happens to be stored under conditions that permit an increase in the temperature of the products, the growth of the milk-souring bacteria will be accelerated and the milk or cream may sour because of this more rapid growth and not because of the action of the thunder or lightning. Milk or cream absolutely free from microörganisms or kept at temperatures below those favorable for the growth of microörganisms will not sour during a thunder storm.

Concentration of Nutrient Solution. Where there is a marked difference between the concentration of the solutions surrounding microörganisms and that of the cells themselves, the effect of osmotic pressure may bring about conditions which check growth or destroy the cells. An illustration of this phenomenon may be found in sweetened condensed milk. As mentioned previously, bacteria do not grow well in such a product, partly because of a lack of moisture. The main reason, however, lies in the fact that cane sugar is added to the condensed milk so that the product contains about 40 per cent by weight of this substance. This yields a thick syrup, especially with the concentration of the milk solids, much more concentrated than the cell substance. As a result, water is drawn from the cell to equalize the pressure. The cell substance shrinks and growth is checked. A strong brine may also affect the osmotic pressure and cause similar results. This is a partial explanation of the effect of salt in retarding the growth of microörganisms in butter and other products where certain organisms are checked by its action.

Temperature. It has been pointed out that milk and dairy products provide an almost ideal food for the growth of most microörganisms. Adequate moisture is furnished in most cases, notably in milk and cream. The atmospheric conditions are not, as a rule, unfavorable. The chemical or physical environment seldom is disturbing in the products intended for food. It follows that in the majority of dairy products conditions are exceptionally conducive to the growth of microörganisms, providing the principal factor, temperature, is satisfactory for cell development.

Different species of microörganisms vary in regard to their relation to temperature. For example, some common molds grow freely at a temperature so low that the bacteria which commonly sour milk will show scarcely any development. Each species has its optimum, maximum, and minimum temperature for growth. So sensitive are microörganisms to temperature that their growth, and, consequently, the changes which they bring about in the particular dairy product concerned may be checked or accelerated by the control of the temperature. The farmer cools his milk to retard bacterial fermentations, souring principally, in order that the milk may reach the consumer in a suitable condition. The factory operator may regulate carefully the temperature of the cream for butter making in order to favor the development of a desirable type of fermentation. As indicated, the activities of microörganisms in dairy products are largely controlled by means of temperature regulation. In fact, the handling of dairy products is largely concerned with the maintenance of proper temperatures for the discouragement or encouragement of the growth, or for the actual destruction of the microörganisms which may be present in the particular product.

The effect of temperature upon microörganisms may be considered under three arbitrary headings:

1. Low temperature: below 50°F. (10°C.).
2. Medium temperature: 50 to 110°F. (10 to 43°C.).
3. High temperature: above 110°F. (43°C.).

Low Temperature. Most organisms survive exposure to low temperatures. In general, however, growth is retarded in proportion to the lowering of the temperature. On the other hand, there are some microörganisms which actually grow at the freezing point of water (32°F. or 0°C.) and slightly below that. Some bacteria actually are able to grow in milk, etc., until it is frozen solid. The presence of salt in butter results in the lowering of the freezing point of the water and buttermilk droplets therein so that certain organisms may develop in butter at quite a low temperature. As a rule, however, growth is retarded below 50°F. (10°C.). For this reason, milk, cream, or other products should be refrigerated properly if there is a desire to check decomposition without modifying the product deleteriously. Fluid milk and cream should not be kept for more than a few days unless they are kept at a sufficiently low temperature to retard bacterial growth. Deterioration may occur in the course of time, however, even though its progress is hindered by the cold. The point to bear in mind is, that refrigeration below 50°F. (10°C.) tends to check the rapid growth of microörganisms.

Medium Temperature. When the temperature of a product reaches a point above 50°F. (10°C.) growth is encouraged, especially between 60 and 100°F. (15.5 and 37.8°C.). Within this range will be found the optimum growth temperatures of the majority of organisms. At 60 to 70°F. (15.5–21.1°C.) the milk-souring bacteria grow most rapidly in comparison with the other types ordinarily present in milk. When these same organisms predominate, as they do in a starter culture, their most favorable growth temperature lies between 68 and 72°F. (20 and 22.2°C.), as will be explained later. When the temperature is raised above 80°F. (26.7°C.), there is a general acceleration of growth of the majority of types present in the product, until a point near 100°F. (37.8°C.) is reached. This range of temperatures (80 to 100°F., or 26.7 to 37.8°C.) encourages, especially, the types of bacteria which produce undesirable fermentations in milk and other products. It should be avoided whenever possible. At 100 to 110°F. (37.8 to 43.3°C.) there are a few organisms which grow actively. These hold a special interest as will be pointed out in subsequent pages.

High Temperature. A few microörganisms are able to grow at temperatures above 110°F. (43.3°C.). These are rare, however. Most organisms are, on the contrary, destroyed at 140°F. (60°C.) or above. The higher the temperature becomes, the more completely are they eliminated, and in proportionately less time. A temperature of 145°F. (62.8°C.) maintained for 30 minutes (pasteurization) ordinarily will kill over 90 per cent of all the microörganisms present in milk or cream, and, fortunately, practically all of those which produce disease. Similarly, exposure at 160°F. (71.1°C.) or higher, for at least 15 seconds, will result in satisfactory pasteurization. At 170 to 180°F. (76.7 to 82.2°C.), an exposure for a few seconds will accomplish approximately the same results. The temperature of boiling water [212°F. (100°C.) at sea level] will destroy most organisms in a few seconds. It requires a temperature of 235 to 245°F. (112.8 to 118.3°C.) for 15 to 30 minutes to destroy all microörganisms, including the resistant spore-forming types. Evaporated milk is treated in this way to destroy all the organisms present.

It may be seen that temperature is an all-important factor in the growth of microörganisms. If the dairyman wishes to control the quality of the product which he is handling, he must exercise keen judgment in the selection of the temperatures which will assist him to accomplish his purpose whether it be preservation, fermentation, or sterilization.

PRODUCTS OF THE GROWTH OF MICROÖRGANISMS

When microörganisms grow upon substances as complex as milk and its products, profound changes are to be expected. A great variety of end-products will be produced because of the utilization of the various constituents as sources of food.

Some of the products that are formed and changes produced by the growing organisms are:

1. Enzymes.
2. Decomposition products of fats, proteins, sugars, etc.
3. Pigments.
4. Toxins.
5. Miscellaneous physical changes.

Enzymes. It has been pointed out previously that, in order to grow, bacteria must be furnished with a suitable food supply. Much of the food material is not in a form, physically or chemically, for immediate utilization. It must be altered in such a way that it can be taken up readily by the cell before it is finally utilized for its nutrition. This process is accomplished largely by means of enzymes, produced by the living microörganisms.

The nature of enzymes, in a chemical sense, is not clearly understood. They correspond most closely in their actions to the catalysts employed by the chemist. They are capable of accelerating a chemical reaction without being altered themselves. After the process takes place, they can be recovered in their original state of activity. Extremely minute quantities of them are able to bring about profound changes. Most of the physiological activities of microörganisms are due to them. Consequently, changes in the constituents of milk and dairy products attributable to microörganisms are brought about by their enzymes.

Types of Enzymes. There are many different types of enzymes, each with its specific action. Some cause hydrolysis, as the production of rancidity of fat, the decomposition of casein, and the splitting of lactose into simpler sugars. Some ferment sugars, changing them to alcohols, acids, carbon dioxide, etc. Others oxidize various compounds, as pointed out elsewhere in this text. Some bring about the reverse action, namely, reduction. Others are able to cause the coagulation of proteins. The casein of milk is acted upon in this way to cause the so-called "sweet curdling" of milk. The enzymes are susceptible to heat, chemical reaction of the substrate, and many other factors. They do not possess the ability to reproduce themselves. They are tremendously important, as the chemical changes in dairy products are largely to be traced to the action of these enzymes produced at one time or another by living cells.

Decomposition Products. Fats are broken down principally into their component parts, glycerol and the fat acids. Defects in butter, such as rancidity, are often of this sort. Some of the characteristic flavor of Roquefort cheese is to be attributed to the action of certain molds upon the fat.

As there is a great variety of proteins, innumerable by-products may be formed when decomposition takes place. They may be broken down into amino acids, other organic acids, alcohols, aromatic compounds, gases, and intermediate products too numerous to mention. The ripening of cheese is a good example of the action of microörganisms on protein.

Sugars are broken down principally into alcohols, acids, water, carbon dioxide, and hydrogen, or the intermediate products. The change of lactose into lactic acid by the action of the milk-souring bacteria is the most common change taking place in milk. Even the mineral compounds may be altered in one way or another.

Pigments. Certain microörganisms secrete pigments of various sorts, such as blue, red, yellow, green, and black. Bacteria may cause remarkable changes of color in milk. Certain yeasts produce pink or red spots on butter or cheese. Molds may bring about marked discoloration of the surfaces of butter and cheese.

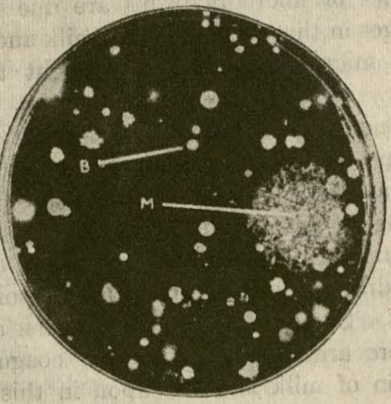


Fig. 18. Colonies of bacteria and molds as they appear on an agar medium in a petri plate after several days' incubation. The bacterial colonies such as *B*, and the mold colonies such as *M*, can be counted easily. This is the way in which the number of bacteria in milk, etc., is determined by the official petri-plate method. One-half natural size.

Toxins. Various types of microörganisms produce poisonous compounds known as "toxins." These may cause serious disturbances in the well-being of man or of animal. The bacteria which cause diphtheria, botulism, and tetanus act in this way.

Miscellaneous Changes. There are bacteria which are able to cause the coagulation of milk without the production of acid, others may produce a ropy condition in milk or cream. As a result of chemical decomposition, an apparently solid dairy product may be transformed into a liquid by the action of microörganisms. Many of these changes will be mentioned later.

METHODS OF COUNTING MICROÖRGANISMS

Several methods are used for the determination of the number of microörganisms in a given dairy product. Consideration will be limited to the most common of these; namely, the plate method. The result of a quantitative analysis of a substance from a microbiological standpoint are recorded in terms of the number of microörganisms per mililiter (cubic centimeter) or gram of the material examined.

In the plate method, a definite quantity of material (milk, cream, etc.) is measured into a glass dish known as a "petri plate." A melted nutrient material is then added to this plate and mixed thoroughly with the sample. This mixture is allowed to solidify and then to stand several days during which time most of the organisms grow. As these organisms reproduce, the progeny remain about the mother cell. In time, their number becomes so great that the mass becomes visible to the naked eye. This mass is called a "colony." After the necessary incubation period, a count is made of the number of colonies on the plate. This is then translated into the number of colonies in a milliliter or gram of the material seeded in that particular plate. For example, if 0.01 milliliter of milk were added to a plate and 240 colonies were observed to develop after incubation, the count per milliliter of the milk would be 240 × 100 or 24,000 per milliliter. This method is useful either for bacteria, yeasts, or molds. It is an estimation of the number of organisms in a given quantity of material, on the basis that each microörganism is able to reproduce itself to such an extent that a visible colony is formed. As a matter of fact, all organisms do not grow under these conditions, nor does the colony count actually represent the total number of individual cells in the given quantity of material analyzed. It is a close approximation, however, and for many years has proved to be of inestimable value in the investigation and control of dairy products. References to the numbers of bacteria are usually given in terms of the count determined by the plate method as outlined. (See also the material in the Appendix and the chapter on Miscellaneous Tests.)

SOURCES OF MICROÖRGANISMS IN MILK

It is important to know the channels through which microörganisms gain access to milk or the products of milk. Since the organisms are widely distributed in nature, it is conceivable that they may be introduced into milk from a great variety of sources. These sources may be grouped conveniently from the standpoint of dairy practice under the following headings: (1) interior of the udder, (2) exterior of the cow's body, (3) atmosphere, (4) utensils, (5) various ingredients added to dairy products, and (6) milker or handler.

Each of these groups deserves special consideration because the number of microörganisms, as well as the types contributed from each source, may have a significant influence upon the quality of the commercial product.

Interior of the Udder. For many years, it was believed that milk drawn directly from the udder of a healthy cow was a sterile fluid, that is, that it contained no living microörganisms. It has been demonstrated, conclusively, in recent years, that freshly drawn milk usually contains bacteria. Ordinarily, however, as the milk is secreted it is free from bacteria. As the milk passes down through the ducts and through the reservoir of the udder, bacteria are picked up from the walls of these passageways, especially along the teat canal. Apparently, certain bacteria exist normally in the udder, while others may be introduced through the opening of the teat from time to time, according to the environment of the animal. Most of these are unable to establish a permanent habitat in the udder. They are washed out, to a large extent, by the first few streams of milk withdrawn from the udder.

The numbers of bacteria which are present in freshly drawn milk vary with individual animals, various quarters of the udder, with the same animal or quarter at various times, with the environment of the animal (cleanliness of quarters, etc.), with the health of the animal, and various other factors. It is found that the first milk withdrawn from the udder (foremilk) usually has a higher bacterial content than that drawn later in the milking process, while the strippings may show a somewhat higher count than the latter. The total number of bacteria present in the milk as it leaves the udder of a normal cow is not very great.

It varies considerably, but 500 to 1,000 per milliliter may be a fair estimate. In some cases, the number is consistently higher, in others lower.

Relation of Udder Bacteria to Human Disease. The principal consideration in the case of bacteria from the udder lies in the possibility that a diseased animal may eliminate disease-producing types of bacteria through the milk which thus becomes a menace to the health of the man or animal consuming such milk. If there are lesions of tuberculosis in the udder, the organisms of tuberculosis may be discharged and be a serious source of infection. Inflammation of the udder, mastitis, commonly called "garget," may be caused by bacteria. If such a condition exists bacteria may be present in tremendous numbers in the milk and be a potential source of septic sore throat among consumers. The bacteria which cause brucellosis (Bang's disease) in cattle may be eliminated in the milk and result in infection of animals drinking this milk. It is also possible that these bacteria may cause disease in man. Fortunately, the majority of the bacteria ordinarily encountered in the udder are harmless and relatively unimportant from the standpoint of their action upon milk or its products.

Milk intended for human consumption should be obtained only from healthy animals. All cows should be tested regularly, especially for tuberculosis and brucellosis, and all diseased animals should be removed from the herd if it supplies milk for human consumption. The cows should be stabled in clean stalls and pastured where there are no bogs, swamps, or stagnant water. Otherwise, undesirable bacteria may find their way into the teat canal from which they may be discharged later into the milk. Furthermore, the first few streams of milk should be discarded. This will tend to keep down the bacterial count and may be done without any particular financial loss, since the foremilk is comparatively low in fat. The improvement in the quality more than compensates for the small loss of milk.

Exterior of the Cow's Body. The condition surrounding the stabling and pasturing of the cows, together with the character of the coat of the animal, is such that considerable contamination of the flanks, tail, and udder is to be expected. This is important because of the presence of large numbers and a great variety of microörganisms in soil, animal discharges, straw, dust, etc., which may accumulate on the body of the cow and be dislodged during the milking process, to fall into the milk pail.

It has been found that under ordinary farm conditions, the exterior of the cow's body may contribute as many as 10,000 bacteria to a milliliter of milk. This is a significant contamination and must be reduced when an attempt is being made to produce milk with a low bacterial count. The use of hygienic methods in the stable, the maintenance of clean stalls, the wiping of the flanks and udder with a clean damp cloth just before milking, and the employment of a small-mouthed pail, or properly "sterilized" milking machine, will remarkably reduce the contamination from this source. The types of organisms which may gain access to milk from this source often are among the most undesirable of all the organisms found in milk or its products. Many of the difficulties experienced in the attainment of high quality in dairy products may be attributed to the contamination of milk with microörganisms from the filth and dirt so frequently to be found on the rear quarters and udder of the cow.

Danger to Humans. Disease-producing types may be present in the deposits on the body of the cow. For instance, a tubercular cow may eliminate the organisms causing the tuberculosis through the fecal or urinary discharges. The organisms may then find their way into the milk. These discharges constitute the principal source of the tubercle organisms in milk. In this way the disease may be transmitted to man or animal consuming such milk.

A serious intestinal disturbance, especially in children, often called "summer complaint" or "infantile diarrhoea" may be caused by infected milk. Organisms of this sort may come from the excreta of the cow and be present in large numbers when hygienic conditions in the dairy are neglected, and especially when temperatures are high enough to encourage the growth of these intestinal types. Hygiene and sanitation are the solutions of the problem of reducing or eliminating this source of microörganisms. The filth from the body of the cow must be reduced as much as possible. The wiping of the udder and flanks with a clean, damp cloth and the use of a small-mouthed pail are extremely important precautions that must be taken if one is to produce a clean, low-count milk.

Atmosphere. At one time, the atmosphere of the stable or dairy was considered as an important source of microörganisms. In reality, it is a relatively minor consideration especially from the standpoint of numbers. Unless the stables or plants are excessively dusty, the contamination is very slight. The types of organisms that may be added from this source may be of some importance, however, particularly the molds. In a creamery or cheese factory, the mold spores may be spread through the air; consequently, butter and cheese must be protected from such contamination.

Ventilation and suitable barn construction are the best preventive measures. Cows should not be milked in a dusty stable Dry feeds or forage should be fed after milking; otherwise, sufficient time should elapse between feeding and milking so that all dust has settled. In a dairy plant, dust may be avoided and all unnecessary exposure of the product must be prevented.

Utensils. The term "utensils" is intended to include all containers or equipment in which, or by which, milk or its products are handled, processed, stored, transported, or merchandised. Utensils are usually the most prolific source of microörganisms as far as numbers are concerned. A milk can, improperly washed, inadequately sanitized or "sterilized," or insufficiently dried, may contribute millions of bacteria to every milliliter of milk placed in it. A neglected milking machine is a very fertile source of contamination. An unsterilized churn, butter tub, curd mill, or anything of the sort, may add large numbers of bacteria, molds, or yeasts to a product. The pipes and pumps so commonly employed in a modern dairy plant are often responsible for excessive contamination unless they are cleaned and sterilized thoroughly. Further instances of the contributions which utensils often make to the numbers of microörganisms in a dairy product will be cited under the discussion of the microbiology of the various products.

Utensils also may be the source of disease-producing types of bacteria. For example, the organisms causing typhoid fever may find their way into milk from utensils that have been rinsed in water that is contaminated with them. The same may be true of other pathogenic organisms. Contamination from utensils may be eliminated by thorough cleansing, followed by adequate "sterilization." In the case of many utensils, such as pails, cans, pipes, pumps, etc., rapid drying and storage in a dry place is advisable. If a dairyman wishes to produce a milk with a low bacterial count he must pay particular attention to the care of the utensils.

Various Ingredients Added to Dairy Products. Substances such as salt, water, gelatin, etc., added to various dairy products, may be a source of microörganisms in large or small numbers, and of harmless or harmful types. These will be considered more fully under the products in which they are employed.

Milker or Handler. The personal element in sanitation as applied to dairying is the key to the whole situation. When the milker, butter maker, cheese maker, or other dairyman is careful, he naturally is the agent who attends to the details of hygiene which lead to a reduction of the contamination from the various sources previously mentioned. When he is careless, uninformed, or willfully negligent, he is responsible for much of the difficulty encountered in the manufacture of first-class dairy products.

A person must be exceedingly careless in his person or habits to contribute, directly, any significant number of bacteria or other organisms. Dirty hands and clothing may be the source of a few organisms—but relatively few. Man is a particularly dangerous source of contamination from the standpoint of the types of bacteria which he may contribute. Several diseases caused by bacteria and spread through milk may be transmitted from the milker or handler to the product under his care. Typhoid fever, diphtheria, scarlet fever, and septic sore throat are sometimes transmitted from a diseased person or carrier through milk to susceptible individuals who consume the infected milk. Some of the most serious epidemics of these and other diseases may have their origin in infection from a diseased individual or carrier who has handled the milk or utensils at one time or another.

Filthy habits, dirty apparel, wet-hand milking, and similar conditions or practices are to be condemned. No person suffering from an infectious or contagious disease, or a carrier of such, should be allowed to handle milk or its products or have a part in the cleansing or care of utensils used for them. Constant attention to the details of hygiene and sanitation is a responsibility which no one engaged in the dairy business can afford to neglect. Man may be a direct or indirect source of serious contamination of such a susceptible food product as milk. He must exercise every precaution to insure a product that is safe and wholesome.

THE FERMENTATION OF MILK

Inasmuch as milk consists of a variety of chemical compounds utilizable by microörganisms, it is to be expected that many changes are possible as a result of the growth of these organisms.

If one were to take an ordinary sample of milk immediately after milking, and place it in a shallow dish at room temperature (70°F. (21.1°C.)) a rather consistent series of changes usually will take place in this milk. These changes may be followed by bacteriological and chemical analyses and by ordinary observation. This sequence of events is sometimes called the "normal fermentation" of milk. It may be divided into four periods, as follows:

1. "Germicidal."
2. Souring.
3. "Neutralization."
4. Putrefaction.

Each of these may be considered briefly.

"Germicidal" Period. Immediately after milk is drawn from the cow, there appears to be a time during which there is no growth of bacteria, and apparently a decrease in the numbers. This diminution is attributed to a "germicidal" or destructive action, or to some unfavorable condition, the nature of which is not definitely known. This "germicidal" period varies considerably in length, usually being shorter at higher temperatures but quite pronounced and more prolonged at lower temperatures. It varies in milk from different cows at different times, from various quarters of the udder, or fractions of milk from the same quarter. It is specific for certain organisms. The "germicidal" activity is destroyed by heating milk to 140 to 176°F. (60 to 80°C.) for 30 minutes. It is of very slight practical significance and may not extend more than a few minutes or a few hours. Immediately, at the close of this period the bacteria begin to grow. This leads to the second period.

Period of Souring. During this period there is rather active growth of many types of microörganisms but the milk-souring types dominate the field and bring about the change of lactose into lactic acid while other changes are taking place to a lesser degree. The souring may continue for several hours or several days, but will reach a maximum when so much acid has been produced that the bacteria which have been responsible for it are inhibited in their growth. This occurs at about 1 per cent acidity.

"Neutralization" Period. In the presence of considerable quantities of acid most bacteria are checked. Molds and yeasts, however, usually will be present and flourish in the acid medium. The acid will be utilized by them, while other chemical changes producing alkaline by-products will accompany the reduction of acidity. A thick mat of mold often may be observed on the surface of the milk at this time. This process may involve several days or weeks.

Period of Putrefaction. When the acid has disappeared owing to the activity of the yeasts and molds, and the reaction of the milk changed from acid to neutral or slightly alkaline, certain bacteria which have remained dormant during the period when acidity was high again enter into an active growth period. These are mostly putrefactive types which attack, principally, the casein. In cooperation with the yeasts and molds, these bacteria completely decompose the solid constituents of the milk with the result that a clear liquid, bearing no resemblance to ordinary milk, is produced. This is the point of ultimate decomposition. Such a substance is no longer fit for food. In fact, it may be actually poisonous. Milk is seldom kept long enough in dairy practice to undergo such extensive fermentation, but the part which microörganisms may play in the decomposition of the complex substances in milk is very clearly illustrated.

SPECIFIC FERMENTATIONS OF MILK

Souring. Souring is the most common fermentation of milk. It is caused by the transformation of lactose (milk sugar) into lactic acid by the action of enzymes produced by microörganisms, principally the so-called "lactic-acid bacteria." Certain yeasts and molds are able to produce lactic acid, but are not so important in this respect as the bacteria. Many bacteria produce lactic acid from lactose. The most important group is typified by *Streptococcus lactis*. This organism has been at various times called *Streptococcus lacticus*, *Bacterium lactis*, and *Bacterium lactis acidi*. It is present in practically all milk and, when

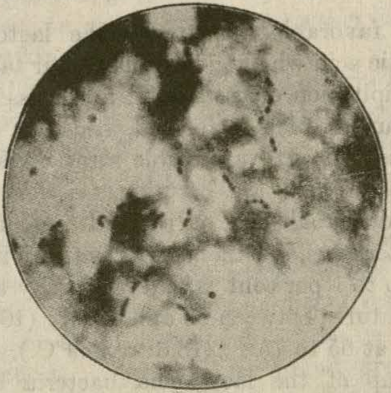


FIG. 19. Photomicrograph of typical milk-souring bacteria (***Streptococcus lactis***). **This illustrates their appearance when a small quantity of sour milk is placed in a thin film upon a glass slide, stained, and examined under a microscope. Magnified 1,475 times.**

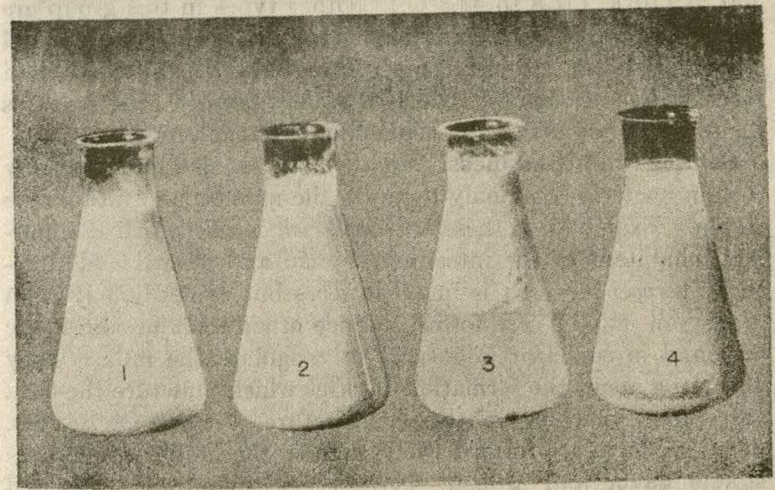


FIG. 20. **Various fermentations of milk caused by bacteria. 1. Souring and coagulation without gas formation or peptonization. 2. Souring and coagulation *with* gas formation. Note the slits and holes in the curd due to the gas. 3. Souring and coagulation *with* gas formation *and* peptonization. Note that the curd is partly digested and rent with gas holes and that it has been forced to the top of the flask by the pressure of the gas. 4. Coagulation due to rennet-like enzyme of sweet-curdling bacteria, and digestion of the curd due to pepsin-like enzymes of the bacteria. The upper portion of the flask is practically all liquid.**

conditions are favorable, it attacks the lactose to produce, principally, lactic acid which gives milk a sour taste and, in turn, causes the precipitation of the casein, a process known as "curdling." The curd, which is formed, becomes a firm, smooth, coagulated mass without any visible signs of decomposition or rupture by gas. There are certain varieties of *Streptococcus lactis* which produce malt-like, burnt, or caramel flavors, ropiness, or other characteristics, but their major activity is the production of lactic acid up to 1 per cent as determined by titration. They grow at temperatures between 50 and 100°F. (10 to 37.8°C.) but most favorably at 65 to 75°F. (18.3 to 23.9°C.).

Another group of the lactic-acid bacteria has as its type *Lactobacillus bulgaricus*, which also produces principally lactic acid from lactose but in larger quantities. The acidity often reaches 2 to 4 per cent. This species will not grow at temperatures below 60°F. (15.5°C.) but will develop very well at 100 to 110°F. (37.8 to 43.3°C.). Other types in this group are *Lactobacillus casei*, which is important in cheese ripening and which grows at a lower temperature than *L. bulgaricus*, and *Lactobacillus acidophilus*, which is widely used in milk cultures for therapeutic purposes in controlling intestinal fermentations.

Souring and Gassiness. Lactic acid is also produced by certain bacteria commonly found in the manure and filth of the stable. Examples of these are *Escherichia coli*, which is a normal inhabitant of the intestines of man and animal and *Aerobacter aerogenes* which is found in feces but comes largely from grain, soil, etc. These forms produce other acids besides lactic acid and in sufficient quantities to coagulate the milk. They also bring about the formation of gases which puncture the curd and cause difficulty in the manufacture of cheese. Besides, other products are formed which give to the milk a very undesirable flavor and aroma. Certain yeast-like organisms and spore-bearing types of bacteria also are able to produce gassiness in milk and cream.

Desirable Aroma and Flavor Production. Organisms are also found, frequently associated with *Streptococcus lactis*, which attack the citric acid of milk. *Streptococcus citrovorus* and *Streptococcus paracitrovorus* are prominent in this connection. As a result of their activity, volatile acids such as acetic acid are formed, as well as diacetyl and other compounds, which contribute to the flavor and aroma. Lactic acid may also be broken down, by *Streptococcus paracitrovorus*, especially. These bacteria are important in producing the desirable flavor in starters used in butter making.

Proteolysis. There are many organisms which show a tendency to break down the casein by a process known as "proteolysis" or "peptonization." Such forms as *Bacillus subtilis*, *Streptococcus liquefaciens*, *Clostridium butyricum*, and *Serratia marcescens* are prominent in this connection. As a result of this decomposition, decided off-flavors and unpleasant odors appear, although in the case of certain cheeses the proteolysis takes place in such a way, by the action of desirable types of bacteria and molds, that a pleasing flavor and aroma develop.

Alkali Production. There will be found present in milk a number of bacteria which attack the salts of organic acids present and change them into alkaline carbonates so that the milk becomes decidedly alkaline in reaction. This fermentation has little commercial significance.

Ropiness. There are a number of bacteria which are able to bring about a peculiar change in milk which is known as "ropiness." Some sticky or gum-like substance is formed by these organisms. This causes the milk to become ropy so that when it is poured from a container long threads of milk will form. These may be several inches or even feet in length. It becomes a very troublesome situation for market-milk distributors but is a characteristic of certain Scandinavian milk beverages.

Certain of the milk-souring types of bacteria may acquire this ability to produce ropiness. Most commonly, however, it is caused by bacteria similar to *Alcaligenes viscosus*, which grows best in sweet milk or cream and when in competition with the mixed flora of milk, at temperatures below those at which milk sours readily. These bacteria occur commonly in surface water and infect the milk directly by being added with water, or indirectly from contaminated utensils, cows, or stable refuse.

The typical ropiness is more of an annoying, than a dangerous, problem. Under certain circumstances, it is a fermentation eagerly sought. It must not be confused with the stringy or slimy condition of milk which sometimes occurs when a cow is suffering from a diseased udder. In this case, the abnormal condition is due to the presence of pus, with tissue cells and blood constituents which cause the sliminess. Such milk is unfit for food.

Sweet Curdling. Occasionally, milk will become coagulated without the action of acid. This may be due to the formation of a rennet-like enzyme produced by bacteria, among which *Bacillus coagulans* and *Bacillus subtilis* are prominent. This curdling may be followed by a digestion of the coagulum and a bitter taste. This change usually takes place in milk that is kept at a low temperature and frequently in pasteurized milk.

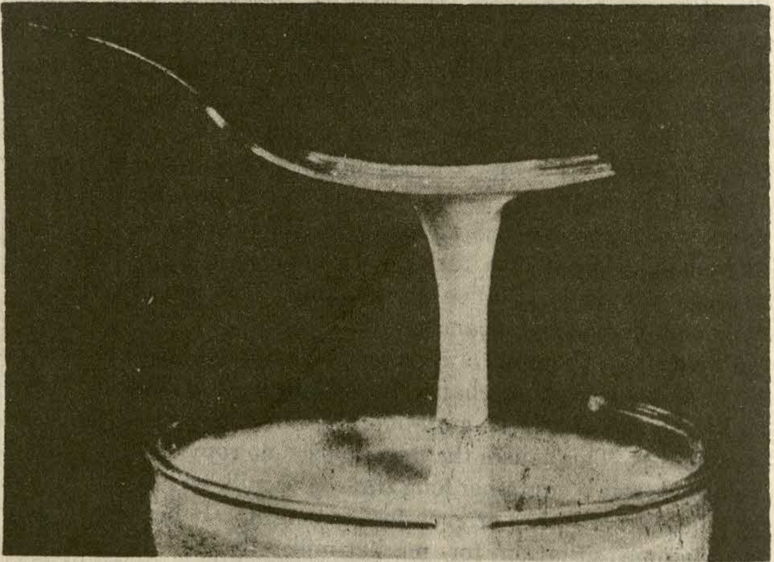


FIG. 21. Ropy milk. Certain types of bacteria produce this ropy condition in milk, and when the milk is poured from a container it forms long, gummy threads which are sometimes several feet long. By dipping a fork into the milk and raising it upward, the ropy condition may be readily observed.

Butyric-acid Fermentation. Sour cream kept at temperatures above those normally used in storage may support the growth of bacteria which are capable of producing butyric acid. This is accompanied very often by gas formation and results in very undesirable flavors and odors. A spore-bearing organism, *Clostridium butyricum*, is capable of this action. It usually is to be traced to contamination from feces, silage, or soil.

Bitter Flavor. A bitter flavor in milk or cream may be due to a number of causes such as feeds or weeds fed to the cow, or to enzymes produced in the udder of the cow when there is some local disturbance there or at a time when the cow is in an advanced stage of lactation, or by the action of microörganisms, such as *Streptococcus liquefaciens* and *Torula amara*. It may be coincident with sweet curdling or decomposition of fat, sugar, or protein, and often occurs in milk held for some time at a low temperature.

Alcoholic Fermentation. A perceptible amount of alcohol may be produced in milk or cream by the action of lactose-fermenting yeasts, which change the lactose into alcohol and other by-products. This often is observed in old cream, especially in the summer.

Production of Colors. Bacteria may bring about remarkable pigmentation of milk. Such colors as blue, red, yellow, and green are occasionally observed. They are due to soluble pigments produced by bacteria and may be accompanied by other changes in the milk. Among these bacteria are *Pseudomonas syncyanea*, *Pseudomonas synxantha*, and *Serratia marcescens*.

Miscellaneous Fermentation. Microörganisms may also produce other changes in milk such as the flavor of turnips, carrots, potatoes, soap, grass, etc., caramel or burnt flavor; and odors resembling a stable or musty room. Most of them are rare, and it is beyond the scope of this text to cover them in detail. There are still other types which seem to exert no perceptible influence upon milk. They may be present in considerable numbers but utilize such small quantities of the constituents of milk that they are hardly noticed. Many of the molds are able to produce complex changes in milk but seldom have the opportunity to exhibit their action because they grow slowly. Milk and cream are used before they can make evident their presence.

THE TRANSMISSION OF DISEASE THROUGH MILK AND DAIRY PRODUCTS

It is understood quite generally that milk and dairy products may transmit disease-producing microörganisms to the consumers of these products. Among the diseases which are most commonly carried through milk and its products are tuberculosis, typhoid fever, diphtheria, scarlet fever, septic sore throat, undulant fever (*brucellosis*), and various intestinal disturbances especially among children.

Tuberculosis is a disease which affects both man and animal. A cow suffering from tuberculosis may discharge the bacteria through the mouth, the fecal or urinary discharges, or directly into the milk. This bovine tuberculosis may be transmitted to man and there manifests itself largely as the glandular, or intestinal type of tuberculosis or a tuberculosis of the bones or skin. Occasionally, it is possible for a person infected with the human type of tuberculosis to transmit the organisms through milk. While the organisms of tuberculosis do not appear to grow in milk they nevertheless are capable of setting up an infection in persons consuming infected milk.

Typhoid fever is chiefly a disease of man. The bacteria causing it may find their way into milk directly from a person suffering from the disease, or from a so-called "carrier" who is a person who harbors the organisms after recovery or even without ever showing any signs of the disease. Infected water may be a source of contamination, especially when used to rinse utensils. In farm homes where a case of typhoid fever exists, milk utensils are often washed in the same dishwater as the dishes from the patient. In this way, milk could be infected eventually from the utensils.

Scarlet fever and diphtheria are also diseases which are most common among human beings. The milk becomes infected from the people who handle the milk or utensils when they are suffering from the disease or while they are acting as "carriers." Infected utensils may also be a source of contamination.

Septic sore throat may result from infection of the milk in the udder of a cow suffering from garget caused by bacteria capable of causing septic sore throat in man, or by direct contamination from a person suffering from the disease.

Undulant fever (*brucellosis*) may be transmitted through milk because of infection of milk in the udder of the cow or goat. The infection from goat's milk is usually termed "malta fever." The infection in cow's milk is traced back to animals infected with the bacteria which cause brucellosis in cattle and which sometimes pass directly into the milk in the udder.

The intestinal disturbances in children, sometimes termed "summer complaint" or "infantile diarrhoea," may be traced to infection from people handling the milk or to contamination of milk with bacteria from the intestines of the cow, which means, in most cases, careless production and excessive filth. There are other diseases which may be carried in milk or dairy products but they occur very rarely.

Determining the Wholesomeness of Milk. How can one tell whether milk contains pathogenic (disease-producing) bacteria or if a given milk is pure and safe? It is possible to determine the presence of specific disease-producing bacteria in milk but it is usually impractical to do so. The organisms may be there in such small numbers that they escape detection. Further, such an analysis requires a great expenditure of time and money. Inoculations must be made into various laboratory animals, such as the guinea pig or rabbit, and the results awaited. This may take several weeks or several months.

If the purity of milk is doubted, it is much more satisfactory to have the cow or cows tested for tuberculosis or contagious abortion, and examined by a competent veterinarian for signs of mastitis and other diseases. If the tests for the diseases are positive, the milk from such animals should not be used for food. If it is a question of intestinal infections, the methods of producing milk, the cleanliness of the cow, and other matters should be ascertained. These defects can be corrected without especial difficulty. If it is a question of man-borne diseases, an examination by competent physicians or health officers should clear up that situation. Much more can be learned from the examination of the cows and of the people handling the milk and from a survey of conditions of producing and handling it than from a laboratory analysis of the milk. The cost is also actually less.

Often it is difficult to trace sources of infection and, consequently, wherever there is any question as to the safety of a given supply of milk, the best precaution to take is either to discard the suspected milk or to pasteurize it properly. Pasteurization is one of the most valuable safeguards which the dairy industry uses for preventing the transmission of disease through milk or dairy products.

CHAPTER VII

THE BABCOCK METHOD FOR DETERMINING FAT IN MILK AND CREAM

Until comparatively recent years, milk and cream were bought and sold only to a limited extent. A century ago, nearly every family was supplied with milk from its own cows, and the dairy products most common on the market, such as butter and cheese, were farm-made. Under these conditions, no special need was felt for a means of measuring the exact amount of fat in milk. When a farmer wished to demonstrate the superiority of a favorite cow, her milk was kept separate and the cream churned alone. Her butter yield for a day or a week was often determined in this manner.

The great increase in city population, beginning in the United States near the middle of the nineteenth century, resulted in the development of a constantly increasing traffic in fluid milk. This was extended further by the movement begun by the establishment of the first cheese factory in 1854, and the first butter factory in 1872. Soon it was found necessary to use some means for detecting the too common adulteration of milk by either skimming or watering. The lactometer, described elsewhere, was among the first devices used for the purpose of detecting these adulterations. The first creamery or butter factory was operated on the plan of bringing the whole milk to the factory. It was apparent that injustice was done by paying the same price for all milk regardless of richness. This plan, however, of paying for all milk by weight regardless of richness was followed for many years and, in fact, among some cheese factories until within very recent years.

The creamery system was soon changed to that of bringing to the factory only the cream which was separated by the gravity method on the farm. With this plan came still greater difficulties, as the variation in the richness of the cream was much more than the variation of the milk. As a result, various plans for testing the cream were devised. The one used most extensively was known as the "oil-test churn" and consisted in churning a small sample of each farmer's cream separately and measuring the percentage of fat which was melted in the glass churning tube. This system was not applicable to milk and, between 1880 and 1890, the introduction of the power centrifugal separator resulted in a great expansion, in butter factories, based upon the delivery of the whole milk. Several chemists worked upon the problem of devising a practical milk test and several methods were suggested which were quicker in operation than the standard method of extraction employed in the chemical laboratory. Among these were Short and Patrick. A satisfactory method for factory use was not forthcoming until Dr. S. M. Babcock, of the Wisconsin Experiment Station, in 1890, announced the method, since that time generally known as the "Babcock test." Few inventions relating to agriculture have been of greater significance or have come into general use so quickly. The Babcock method now is used universally in the United States and Canada. A remarkable fact is that after over 60 years of use no fundamental change or improvement has been made in the method. At the present time, milk and cream to the value of approximately $3,500,000,000 are marketed yearly in the United States, mostly on the basis of the milk-fat content which is determined by the Babcock method. Another factor responsible for the widespread use of the Babcock test was the refusal of the inventor to patent the method for his own financial benefit.

In addition to the use of the test for evaluating milk for sale, a constantly growing use is in connection with the keeping of records of individual cows to determine their production. In time, probably, the fitness of practically all cows to remain in their owners' herds will be judged, in part, by means of this test.

General Procedure. Previous to the work of Dr. Babcock, others had discovered that strong acid would digest the proteins of milk and free the fat globules so that they might run together. Dr. Babcock's special contribution was the application of centrifugal force to the samples after the fat has been freed by the action of sulfuric acid. By this means, it is possible to gather the fat at the surface of the fat-and-acid mixture and to measure it on a suitable graduated scale.

In brief, the procedure in making a Babcock test of milk is as follows: By the use of a pipette, the milk sample (17.5 milliliters) is measured into the milk-test bottle, after which commercial sulfuric acid (17.5 milliliters) is added and the two thoroughly mixed. The bottle containing the mixture is then centrifuged for 5 minutes to bring the fat to the surface. Sufficient water then is added to bring the contents to the base of the bottle neck. The bottle is again centrifuged for 2 minutes and sufficient water then added to bring the fat into the graduated part of the bottle neck. The bottle is centrifuged again for 1 minute to gather the fat into a coherent column. The reading of the fat percentage is made from the graduated scale on the neck of the bottle.

Principles Underlying the Test. The Babcock method for determining the fat percentage in milk and other dairy products is based upon two principles. The first is that concentrated sulfuric acid, when mixed with milk in correct proportion, will digest (hydrolyze) the proteins of the milk, breaking them down into simpler constituents in which form they no longer are capable of maintaining the fat droplets in the emulsified state of dispersion. Thus freed, the fat globules may rise to the surface of the liquid and join together (fuse) into a single mass of fat. The heat generated by the reaction between the sulfuric acid and the milk melts the fat globules and permits them to run together. The heating of the liquid also lowers the viscosity of the acid mixture which makes the conditions more favorable for the movement of the fat droplets to the surface.

The second principle involved concerns the manner of separating and collecting the fat. The contents of the test bottle are a mixture of fat and an acid solution of the other milk constituents. The fat, at the temperature reached during testing, has a specific gravity of 0.9 compared to approximately 1.43 for the acid mixture. In the centrifuge, the greatest force will be exerted on that portion of the mixture having the highest specific gravity, which, in this case, is the acid solution. The centrifuge, used in making the test, is constructed in such a manner that the test bottles assume a horizontal position during the whirling. The fat is forced toward the center; that is, toward the neck of the bottle.

When milk is sold, except in the case of the retail trade, weight rather than volume is the unit used. It is desirable, therefore, that the fat percentage be likewise on a weight basis. For instance, in calculating the pounds of fat in a given quantity of milk, it is necessary to multiply the percentage figure by the pounds of milk rather than by the gallons. For this reason, the basis of the test is weight, 18 grams of milk being the amount used. As a matter of convenience, the amount to be used is measured rather than weighed. For this purpose a pipette calibrated to hold 17.6 milliliters at 68°F. (20°C.) is used. It has been found that 1/10 milliliter adheres to the pipette and, as 1 milliliter of average milk weighs 1.032 grams at 60°F. (15.6°C.) 17.5 milliliters of milk are equal to 18 grams.

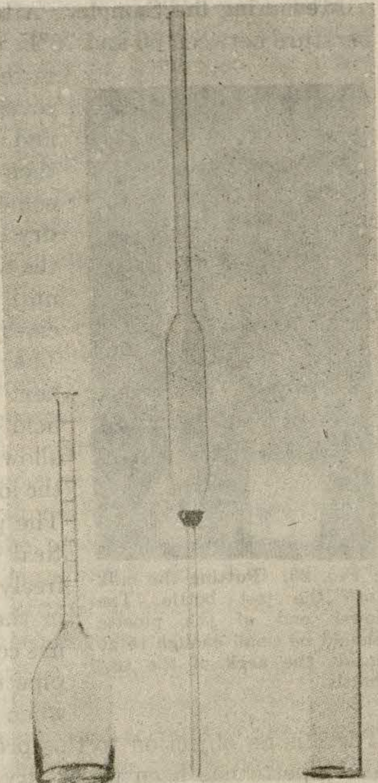


FIG. 22. Babcock milk-test bottle, pipette, and acid measure.

Testing Whole Milk. The apparatus required includes (*a*) the test bottles, (*b*) a pipette graduated to hold 17.6 milliliters, (*c*) an acid measure graduated to 17.5 milliliters, and (*d*) a centrifuge; in addition, (*e*) sample bottles, (*f*) a mixing jar and thermometer, and (*g*) dividers should be available. A supply of commercial sulfuric acid is necessary. This should have a specific gravity of 1.82 to 1.83 at 68°F. (20°C.) and be free from dirt and sediment.

The first precaution is to be certain that the milk at hand is a representative sample of the entire amount which the completed test is to represent. More errors are made in this connection than in conducting the details of the test. The next step is to take the temperature of the milk, and if it is not between 60 and

70°F. (15.5 to 21.0°C.) it is brought within these limits, because extreme temperatures affect the accuracy of the measurement of the milk. Another reason for controlling the temperature is to insure proper action of the acid upon the milk. Beyond the temperature figures given above, the action of the acid may be influenced to such an extent as to give an unsatisfactory result.

Measuring the Sample. After bringing the sample to a temperature between 60 and 70°F. (15.6 to 21.1°C.), it is thoroughly mixed by pouring it back and forth several times from the sample bottle and the mixing glass. The pipette then is filled by suction to a point somewhat above the graduation. The dry forefinger is slipped quickly over the top and the milk allowed to escape until the bottom of the meniscus coincides with the mark on the pipette. The measured sample is transferred next to the test bottle. It is well to hold the test bottle at an angle and allow the tip of the pipette to touch the lower side of the neck of the bottle. The pipette should be held in a vertical position and allowed to drain freely. Blow out the milk remaining in the pipette tip after free outflow has ceased. Some prefer to insert the pipette into the neck of the bottle when transferring the milk sample. There is no objection to this procedure, provided the outside of the pipette has been wiped dry; otherwise, too much milk will be delivered to the bottle. Furthermore, if too much milk is adhering to the outside of the pipette point, it will interfere with the outcoming air which is being displaced by the milk, and the consequent loss of milk in the bubbles that escape will necessitate making the test over again.

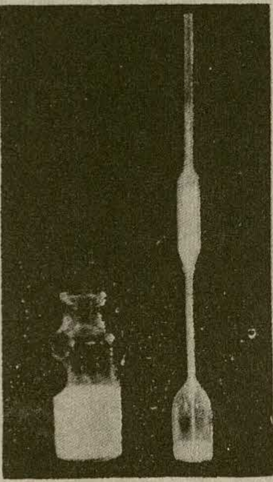


Fig. 23. Putting the milk into the test bottle. The lower end of the pipette should be small enough to go inside the neck of the test bottle.

In any case where accurate results are desired, it is the best practice to make two tests of the same sample so that any mistake made in testing or reading one bottle will be detected on the second one.

Adding the Acid. Fill the acid measure to the graduation indicating 17.5 milliliters with sulfuric acid (commercial, specific gravity 1.82 to 1.83 at 68°F. (20°C.)). The acid should be within the same limits of temperature, 60 to 70°F. (15.5 to 21.1°C.), as given for the milk. It is especially important to avoid higher temperatures. When adding the acid, hold the test bottle at an angle of a little less than 90 degrees and pour the acid slowly and carefully into the neck, taking care not to fill the neck to such an extent as to stop the free escape of the air; otherwise, the inflow of the acid may be stopped suddenly and a portion overflow onto the fingers of the operator. It is best to add about two-thirds of the measured amount at first. Then rotate the bottle with the hand, gently at first, taking care not to fill the bottom of the neck with the contents, and then rotate more vigorously as the curd is dissolved. Then add the remainder of the acid and shake rather vigorously, always using a rotary motion to prevent spilling the contents. Vigorous shaking should be continued for 1 full minute after the uniform dark color is noticed.

Centrifuging. The bottles should be placed at once in the centrifuge and whirled for 5 minutes at the proper speed. Most Babcock centrifuges now on the market either are geared so that proper speed is obtained when motor driven, or, as in the case of the hand-operated centrifuges, the correct speed usually is indicated on the crank of the machine. A more complete discussion of proper centrifuge speed will be found in the paragraph on centrifuges. The bottles must be placed in the machine in such a manner as to balance one another. To do this properly requires an even number of bottles. Sometimes, in case of an odd number, a bottle filled with water is used to balance but this only partially serves the purpose on account of the marked difference in specific gravity between the water and the acid mixture.

Occasionally, one wishes to centrifuge only two bottles. These must be placed on opposite sides of the centrifuge wheel, and if the cups supporting the bottles are in pairs, each bottle should be placed in the outside cup of the pair. Bottles whirled in the inside cup with the outside cup empty are likely to break. Some operators prefer to fill two bottles with water and place them in the two inside cups next to the tests, but with most centrifuges this practice is unnecessary.

The centrifuge should be started and stopped with care in order not to injure the centrifuge or break the test bottles. At the end of 5 minutes stop the centrifuge and by means of the pipette or other suitable device add soft water to the test bottles until the contents are close to the base of the neck. The water should be at a temperature of not less than 140°F. (60°C.)

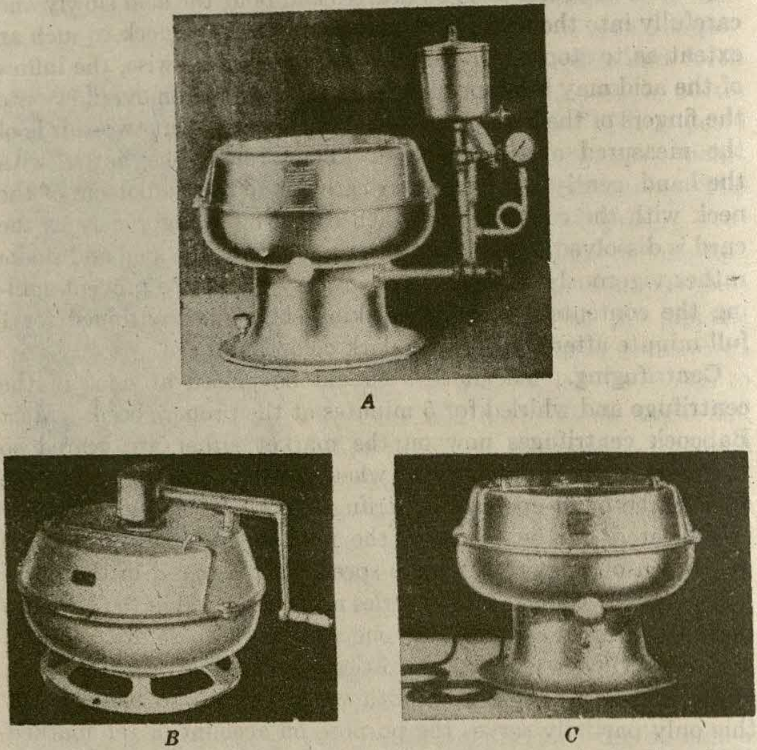


Fig. 24. Centrifuges used in testing milk by the Babcock method. Centrifuges are made to operate by *A*, steam; *B*, hand; or *C*, electric power.

In adding the water, allow it to flow down the side of the neck while the bottle is held at an angle in order not to disturb the fat layer. If hard water is used, it is advisable to add a few drops of sulfuric acid to it before using. The centrifuge then is run for 2 minutes at the same speed as before, after which water is added to bring the fat column well within the limits of the graduated scale on the bottle neck. Care must be exercised lest too much water be added and the top of the fat column raised above the top of the scale. The centrifuge is operated again, this time for 1 minute. The test bottles are next placed for 5 minutes in a water bath maintained at a temperature of 135°F. (57.2°C.) to 140°F. (60°C.) and deep enough so that the hot water is level with the top of the fat column. The tests then are ready for reading.

Reading the Test. Each test should be read quickly after the bottle is taken from the bath. The space filled by the fat column is noted and read from the straight line on the surface, the top of the meniscus, to the extreme lower line of the fat in the lower meniscus. As a matter of convenience, a pair of dividers generally is used. The prongs of these dividers should open and close easily and yet show sufficient resistance, so as to prevent spreading once they have been set. One point is placed at the lowest surface of the fat column and the dividers adjusted to bring the other point to the extreme top of the upper meniscus. Without changing the spread, the lower point of the dividers is now placed at zero on the graduated scale, the upper point then showing the reading in percentage by weight.

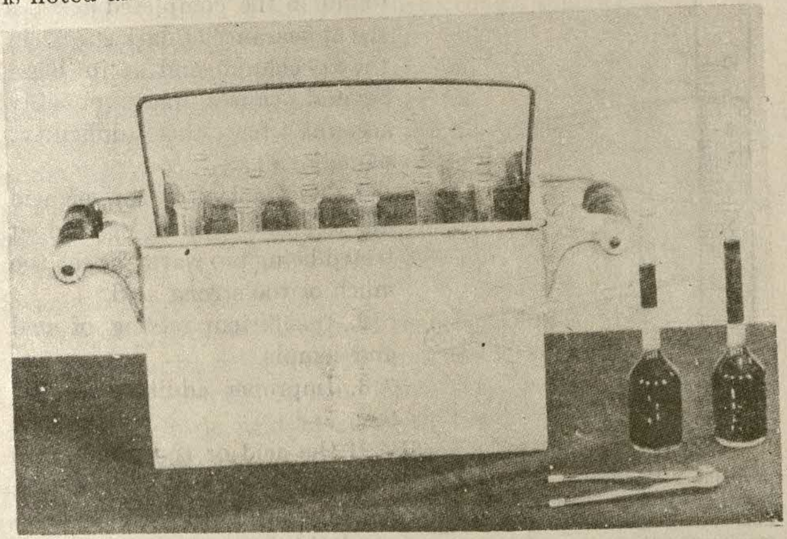


Fig. 25. Water bath. The test bottles are placed for 5 minutes in the water bath at a temperature of 135°F. before the readings are made.

Defective Tests. Difficulties often are encountered in conducting the Babcock test of various milk products. Frequently, the fat column is dark-colored and contains black particles, especially at the base. Sometimes the fat column is light in color, often cloudy, and a mass of white material may be found at the base. Again, the fat may be clear, and the base of the column clearly defined, yet bubbles are found at the surface which obliterate the upper meniscus. These difficulties usually may be avoided by one who understands the chemistry involved.

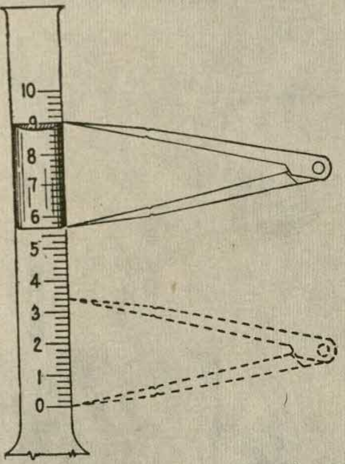


Fig. 26. Reading the fat column in a Babcock milk-test bottle. The reading is taken from the straight line, which marks the top of the meniscus at the surface of the fat, to the extreme bottom of the fat column. Dividers are used as a matter of convenience.

One of the most common defects found in the completed tests is the appearance of dark specks in the fat column and at its base. Several causes may possibly account for this difficulty; namely,

1. Too violent action of acid due to either (*a*) acid or product tested being too warm, or (*b*) too much or too strong acid.
2. Insufficient mixing of acid and sample.
3. Improper addition of water.

If the acid or the product to be tested is too warm, the action of the acid is too rapid. The result is that some of the milk solids are charred by the acid, thus forming on the particles a layer which is impervious to the action of the acid. They rise to the surface with the fat because they contain no acid but do contain some fat. The remedy is to adjust the temperature of both the acid and milk to be tested to not over 70°F. (21°C.) before beginning the test. If the action of the acid still is too violent, further reduce the temperature of the acid and milk or reduce the amount of acid used by about one-tenth. About the same appearance of the fat column results when the operator fails to agitate the contents of the bottle sufficiently before centrifuging. It is not sufficient merely to shake the bottle until the brown color appears; they should be shaken vigorously for at least a minute after that.

In certain practical plants the operators add water to the tests before they are centrifuged. If this is done too quickly, it counteracts the action of the acid before all the curd has been dissolved and a cloudy fat column results. Occasionally, at the last filling of the bottles the water is allowed to plunge directly into the fat collected at the base of the neck. This carries the fat downward into the acid mixture and some of the dark particles there may be carried upward with the fat, especially if the contents of the bottle have cooled somewhat.

Occasionally, a light-colored, cloudy fat column is observed. The most common cause of this is insufficient action of the acid, which may be brought about because (*a*) the acid or the product being tested is too cold, or (*b*) the acid is too weak, or (*c*) too little acid is used. A second cause is the addition of water before the action of the acid is complete.

The appearance of bubbles or foam at the upper meniscus may result from the addition of hard water in conducting the test. The sulfuric acid reacts with the carbonates producing carbon dioxide gas. This difficulty may be eliminated either through the use of soft water or by adding a few drops of sulfuric acid to hard water before adding it to the test bottle.

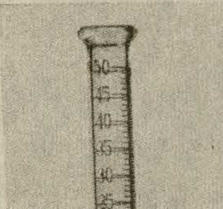


FIG. 27. Bottle for testing cream by the Babcock method. Nine grams of cream are used with this bottle.

TESTING CREAM

Variations from Milk-test Procedure. The Babcock method has been applied to cream, not by Babcock but by others. In this application certain modifications of the method as used for milk have been necessary. These differences are:

1. The use of a test bottle having a neck of greater capacity than the neck of the milk-test bottle.
2. The proper amount of cream determined by weight rather than by volume.
3. The use of an approved meniscus remover such as glymol or pure

white mineral oil, commonly dyed red, to eliminate the upper meniscus of the fat column before reading.

4. The optional use of a 9-gram sample instead of an 18-gram sample as in the case of milk.

5. When a 9-gram sample is used, it is necessary either to use only 8 to 12 milliliters of sulfuric acid, or to add 9 milliliters of cold water to the cream before adding 17.5 milliliters of acid.

6. It is not necessary to control the temperature of the cream before measuring the sample into the bottle, as in the case of milk.

The need for a test bottle having a greater capacity in its neck than that in the neck of the whole-milk test bottle is due to the much greater percentages of fat contained in cream than in milk. It is obvious that the fat column rising over a sample of cream will occupy considerably more space than is required for the fat from an equal quantity of milk.

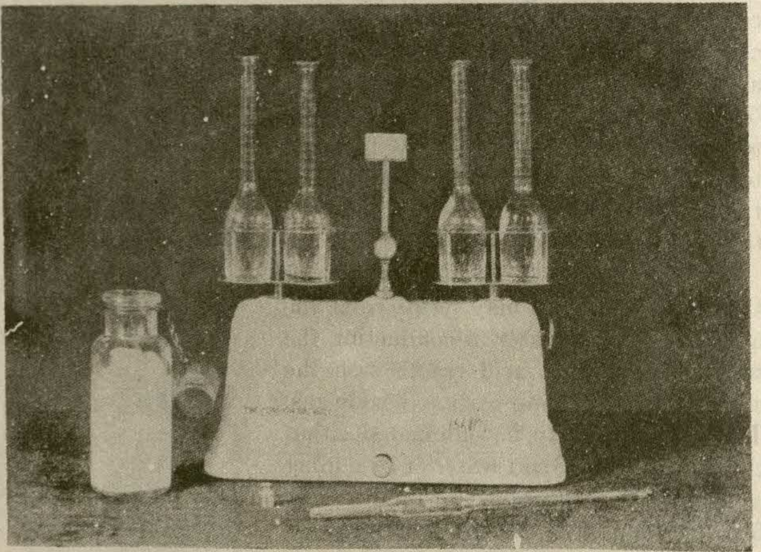


FIG. 28. Scales for weighing cream samples for testing. The cream sample must be weighed, not measured, as is the case with milk. The bottle containing cream is an approved type for composite samples.

Why Cream Samples Are Weighed. The milk test is based upon an 18-gram sample obtained by volumetric measurement in a pipette. Cream must be weighed rather than measured because it is impossible to obtain a definite weight by taking a particular volume. There are three factors concerned: First, the specific gravity varies considerably with the fat content. Cream containing 20 per cent of fat does not have the same volume per unit of weight as does, for example, 40 per cent cream. A certain amount of air also is incorporated in cream, the amount varying with conditions to which the cream has been subjected. The third factor is the viscosity, which varies widely with different lots of cream. As a result, the amount adhering to the pipette is far from constant.

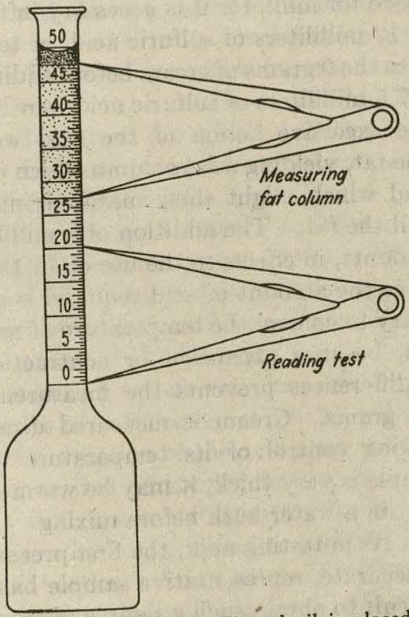


FIG. 29. Reading the cream test. Mineral oil is placed on the surface to remove the meniscus. The reading is then made from the upper to the lower extremes of the fat column.

Elimination of Meniscus. It is common practice to add a few drops of an approved meniscus remover to flatten the upper meniscus of the fat column just before reading the cream test. The use of this procedure has been found to yield results which agree most closely with determinations made by the Roese-Gottlieb ether extraction method. Glymol or pure white mineral oil to which a red dye has been added is commonly used. The colored oil is often called "red reader" by the trade. The mineral oil should have a specific gravity of not more than 0.85

at 68°F. (20°C.) and should be allowed to flow down the side of the neck when adding in order to obtain a distinct line of separation at the surface of the fat column.

Size of Sample Taken. Another difference between the methods for cream and milk testing is in the size of the sample tested. For the whole-milk test an 18-gram sample is always used. Eighteen-gram samples are sometimes used for cream testing also, but in many localities 9-gram samples are used. The use of 9-gram samples necessitates still further variations from the method used for milk, for it is necessary in this case either to use only 8 to 12 milliliters of sulfuric acid, or to add 9 milliliters of cold water to the 9 grams of cream before adding 17.5 milliliters of acid. If 17.5 milliliters of sulfuric acid were added to 9 grams of cream, the excessive action of the acid would result in a charring of the fat, yielding a fat column which could not be read accurately and which might show materials other than fat, or fail to show all the fat. The addition of 9 milliliters of water to the cream amounts, in effect, to the use of an 18-gram sample of cream, so far as the amount of acid required is concerned.

It is necessary to control the temperature of milk within rather narrow limits, because expansion or contraction due to wide temperature differences prevents the measurement by volume of exactly 18 grams. Cream is measured directly by weight, however, making control of its temperature unnecessary. If the cream sample is very thick, it may be warmed to 85 to 95°F. (29.4 to 35°C.) in a water bath before mixing.

Procedure. As in testing milk, the first precaution is to make sure that an accurate, representative sample has been obtained. It is more difficult to obtain such a sample of cream than of milk, because of the higher fat content. The sample is mixed thoroughly by pouring from the sample bottle to the mixing glass and back again several times.

Nine or eighteen grams of cream are next weighed into each of two cream-test bottles of a capacity and construction corresponding to the amount of sample to be used. The bottles are placed one on each pan of a cream balance and the scale brought into balance by means of an adjusting device with which the scale is fitted. A 9- or 18-gram weight is placed on one pan and cream measured into the bottle on the opposite pan until the scale again comes into balance. The weight is then removed and cream measured into the bottle on the pan from which the weight was removed until a balance is again reached. Each bottle then contains cream in a quantity equal to the 9- or 18-gram weight used.

The next step is to add sulfuric acid. If 18-gram samples of cream have been weighed into the bottles, then about 17.5 milliliters of acid are added. If 9-gram samples have been used, then a choice of two different procedures is offered, depending upon the type of test bottle in use. Two types of these bottles are available, both having necks of a capacity such that the percentage may be read directly for 9 grams of sample, but with bodies of different capacity, one being about 25 milliliters, the other 50 milliliters. If the smaller bodied bottle is used, 8 to 12 milliliters of sulfuric acid are added. If the larger one is used, 9 milliliters of cold, soft water are added to the cream and then 17.5 milliliters of sulfuric acid.

Regardless of which of the above procedures is followed, it is necessary to mix the acid and the sample immediately after the addition of the acid. This is done exactly as described for milk, by a gentle rotary motion until a uniformly dark color appears and then by vigorous shaking for at least 1 minute. When acid is added to undiluted cream samples, it is recommended that 5 to 10 milliliters of soft water, at 140°F. (60°C.) or above, be added to slow the reaction of the acid after the mixture has been shaken and the desired dark color developed.

The bottles next are centrifuged for 5 minutes. Hot water (140°F. (60°C.) or higher) is added to float the fat to the base of the neck of the bottles. A few drops of sulfuric acid should be added to hard water before it is used. The bottles are next centrifuged for 2 minutes.

Hot water is added to float the fat well up into the neck of the bottle, and the bottles again centrifuged for 1 minute. The bottles next are removed from the centrifuge and placed in a hot-water bath at a temperature of 135°–140°F. (57.2–60°C.) with the level of the water above that of the fat. After 5 minutes in the water bath, a few drops of red reader are allowed to run gently down the inside of the neck and the length of the fat column from the extreme bottom to the junction of fat and red reader is measured with dividers. The percentage of fat is read from the scale on the neck of the bottle, as in the case of milk.

DETAILS OF MILK- AND CREAM-TEST BOTTLES, CREAM SCALES, AND CENTRIFUGES

Milk- and Cream-test Bottles. Detailed specifications for Babcock milk- and cream-test bottles have been set forth by the Bureau of Standards of the U.S. Department of Commerce. These specifications have been approved and adopted by the American Dairy Science Association, the Association of Official Agricultural Chemists, and dairy officials of many states. Complete specifications are published in the handbook entitled "Official and Tentative Methods of Analysis of the Association of Official Agricultural Chemists." The following test bottles are recognized as official:

Milk-test bottle

8 per cent, 18 gram, 6 inch, with 0.1 per cent graduations.

Cream-test bottle

50 per cent, 9 gram, short-necked, 6 inch.
50 per cent, 9 gram, long-necked, 9 inch.
50 per cent, 18 gram, long-necked, 9 inch.
(All bottles with 0.5 per cent graduations.)

The standard milk-test bottle (shown in Fig. 22) is composed of a bulb with a capacity of about 50 milliliters to which is attached a slender neck carrying graduations ranging from 0 to 8 per cent. The capacity of the neck for each whole per cent must be 0.20 milliliter; therefore, the capacity of the total graduated portion should be 1.6 milliliters. This is based on the fact that in order to permit the reading of the test directly in per cent by weight, the total graduated portion must hold 8 per cent of the 18-gram sample or 1.44 grams. Since the density of milk fat when the test is read at 135 to 140°F. (57.2 to 60°C.) is very nearly 0.9, the 1.44 grams of fat will have a volume of 1.6 milliliters.

When the Babcock test was first put into general use, a 10 per cent milk bottle was used which was graduated in divisions of 0.2 per cent. Although this bottle is still used in a few instances, it is not recommended because of the greater chance for reading errors. A 10 per cent milk bottle with 0.1 per cent divisions has also appeared on the market but has not been approved by official organizations.

Many types of cream-test bottles have been made and tried. A special problem arises in designing an accurate cream-test bottle due to the presence of a much larger volume of fat to be measured. Whereas the 8 per cent milk-test bottle has a capacity of 1.6 milliliters in the graduated portion, a 50 per cent cream-test bottle designed for an 18-gram sample must have a capacity of 10 milliliters between the 0 and 50 per cent marks. To meet this requirement, the cream bottle is made with a larger neck, which is accomplished by either increasing its diameter or length. When the diameter of the neck alone is increased, the accuracy of the reading is reduced because slight errors in the measurement of the height of the fat column cause relatively large errors in the reading. On the other hand, if the bore of the neck is made smaller in order to facilitate accurate reading, then the length of the tube must be unduly increased to insure sufficient capacity for the fat from high-testing cream, and the bottle becomes top-heavy and is more subject to breakage. The problem of design is reduced considerably through the use of a 9-gram sample of cream since the required capacity of the neck is just half that needed for an 18-gram sample. It must be borne in mind, however, that as the size of the sample to be tested is decreased, the errors in measuring are increased correspondingly, so that the increased accuracy in reading the sample is counterbalanced by the greater error likely in measuring.

The 50 per cent, 9-gram, short-neck bottle is the most commonly used at the present time, among those listed above. It is not so subject to breakage as the taller bottles and will fit all Babcock centrifuges better. Where greater accuracy in reading is desired, the 9-gram, long-neck bottle is recommended. It has the disadvantages, however, of being more subject to breakage and will not fit into centrifuges designed for 6-inch bottles. An economical advantage of both bottles is the obvious saving due to the smaller amount of cream and acid required in testing.

The 50 per cent, 18-gram, 9-inch bottle finds favor with some because it offers the accuracy on weighing the cream that the larger sample affords, and, at the same time, permits quite accurate reading because of the elongated narrow-bore neck. It has the same disadvantages, however, from the standpoint of handling as the 9-gram, long-neck bottle.

Cream Scales. For the measurement of cream into the test bottles, a small scale known as a "cream balance" or "cream scale" is necessary. Although either the torsion or beam type may be used, the torsion type shown in Fig. 28 is by far the more common. Its weighing pans usually are constructed with a light frame to prevent the bottles from tipping or sliding off, and each pan may hold from one to six bottles, depending upon the model. The scale is equipped with one of several types of adjusters so that the point of balance may be shifted at will.

The required sensitivity of such a balance is often specified by state regulations. Usually, a sensibility reciprocal of 30 milligrams is required; that is, the addition of 30 miligrams to either pan of the scales, when loaded to capacity, shall cause a deflection of the pointer of at least one division on the graduation.

Cream scales must be kept clean, set level upon a stable support, and be protected from drafts in order to assure accurate weighings. Weights with a tolerance of not more than 5 milligrams should be used.

Centrifuges. The centrifuge consists of a horizontal wheel supported on a vertical drive shaft. The periphery of the wheel carries bottle holders, usually in pairs, so hung that they may swing outward into a horizontal position due to centrifugal force as the wheel gains speed. This entire mechanism usually is enclosed in a suitable steel or iron protector, which serves both to prevent quick cooling of the contents of the bottles during centrifuging, and to avoid injury to the operator when breakage of bottles accidentally occurs during operation.

Many different types of centrifuges are on the market. Some are operated by hand, and others by power, either steam or electric. Centrifuges designed for use with the Babcock method may be bought in sizes holding from 2 to 36 bottles and designed to handle either the 6-inch or 9-inch bottle. Some of the electrically operated machines are supplied with heating devices for the purpose of keeping hot the contents of the bottle during centrifuging. This feature is desirable and is required in some states, but in purchasing a machine one should make certain that this heater and its wiring are protected properly against the action of the acid which is certain to be spilled in the machine at various times due to accidental breakage of the bottles; otherwise, a short circuit may result and the heater may be ruined. The heated centrifuge should be equipped with a thermometer and a temperature of from 130 to 135°F. (54.4–57.2°C.) maintained, preferably through the use of a thermostat.

The steam-driven machine has an obvious advantage in heating the sample because it permits live steam to escape into the centrifuging chamber during operation and thus keeps the contents hot. Some people object to this type of machine because of the water and rust which attend its operation.

Centrifuge Speed Required. Babcock's original tests were centrifuged at 800 r.p.m. on a wheel 18 inches in diameter. It was found by him that incomplete separation of the fat resulted at lower speeds, while higher speeds gave no better results than those obtained at 800 r.p.m. It is obvious that wheels of a diameter less than 18 inches must travel at a speed faster than 800 r.p.m. in order to generate the same amount of centrifugal force, and machines of a diameter greater than 18 inches need not travel so fast as 800 r.p.m. When the weight of the objects being centrifuged is always approximately the same, as is true of Babcock test bottles and contents, the square of the r.p.m. of the wheel must vary in inverse proportion to the radius. Thus, at two different radii the velocities must vary according to the formula

$$\frac{r_0}{r_1} = \frac{v_1^2}{v_0^2} \quad \text{or} \quad r_0v_0^2 = r_1v_1^2.$$

Using Babcock's original figures we may calculate the speed required at any other diameter by substitution in the above formula.

Thus,

$$rv^2 = 9 \times 800^2$$

or

$$v = \sqrt{\frac{9 \times 800^2}{r}}$$

where r is the radius for which we wish to calculate the reel speed, and v is the velocity in r.p.m. required for the radius r.

The following table shows the wheel speeds required of different-diameter machines, calculated by means of the above formula.

Diameter, inches	R.p.m. of wheel	Diameter, inches	R.p.m. of wheel
12	980	18	800
14	907	20	759
16	849	22	724

In order to determine the speed at which a centrifuge should be operated, measure the distance from the center of the wheel to the bottom of one of the bottle cups held in the horizontal position it assumes while the wheel is in motion. This measures the radius of the wheel and may be used in the formula shown above to determine the speed at which it should travel, or the diameter may be obtained if the radius is doubled and the required speed read from the foregoing tabulation.

CHAPTER VIII

COMMON DAIRY PROCESSES

CREAM SEPARATION

When the milk fat is concentrated into a fraction of the original milk, that portion is known as "cream." Cream is not a definite, specific substance. The use of the words "separating cream" often leads to an erroneous conception regarding the nature of cream. It should be understood that the portion of the cream not fat is essentially the same as the skim milk represented by the part remaining as skim milk when the cream was removed. There is no exact limit which may be set regarding the fat content necessary to justify the use of the term "cream." In a commercial sense, the term seldom would be applied to a product having less than 18 per cent milk fat. Cream, as sold for household use, contains, as a rule, from 20 to 25 per cent fat. Higher fat percentages also often are available under specific terms, such as "whipping cream." Cream as received at butter factories usually contains from 25 to 40 per cent fat. Cream is separated for several purposes. The most important is to obtain a product from which butter may be churned more economically than from whole milk. Cream also provides a richer product than milk for table use or for certain manufacturing purposes, more especially for ice-cream making.

Historical. The extensive use of cream for either of these purposes is relatively modern. Ancient peoples are known to have used milk freely and it is probable that they at times used cream that rose to the top of the milk which had been held some time in containers—although there is little in ancient literature to suggest such use as common. It is well established that in early times butter was produced by churning milk. Thus, in one of the oldest parts of the Bible occurs the statement, "surely the churning of milk bringeth forth butter." Probably one reason for the limited use made of cream in early civilizations was the fact that these peoples lived in warm climates and without suitable means of cooling and preserving milk, without which the use of cream is certain to be rather unsatisfactory. For this reason, the use of cream as a part of the process of butter making developed chiefly in the northern latitudes where civilization was established later. It is not clear when the use of cream for butter making became common. The extensive use of cream for household purposes is a development of very recent years, and was made possible by the development of suitable means for securing the cream in a fresh condition and maintaining the condition by cooling until consumed.

It is probable that the practice of gravity creaming was followed, to some extent, by most milk producers for at least a century previous to the invention of the centrifugal separator. Milk was sometimes set in shallow pans, sometimes in deep cans, and sometimes diluted with water for creaming. The advent of the centrifugal cream separator, in 1879, marked the beginning of sweeping changes in the dairy industry. Many of these changes were made possible by this machine, and others were indirectly the result of its use.

Basic Principle of Separation. Separation of cream from milk is possible because of a difference in specific gravity between the fat and the liquid portion or serum. Whether separation is accomplished by gravity or centrifugal methods, the result is dependent upon this difference. The serum or skim-milk portion possesses an average specific gravity of 1.036, while that of milk fat is about 0.930. When milk is allowed to stand, the force of gravity affects both serum and fat, exerting a downward pull on each which is proportional to its specific gravity. As the serum is the heavier, it assumes a position below the fat, just as water will form a layer below oil when a mixture of the two is allowed to stand. The analogy is not complete, however, for, when oil rises on water, it forms a continuous film at the surface, but, when the milk fat, in the form of globules, rises to the surface of milk, the globules maintain their identity at the temperatures below their melting points, preventing the formation of a layer of milk fat; instead, a considerable amount of serum remains with the fat. This combination of the fat of milk, existing in the form of globules dispersed in a portion of the serum of the milk, composes the product commonly recognized as cream.

When milk is revolved swiftly in such a device as a separator bowl, where the generated centrifugal force is about one-thousand times greater than that of gravity, the milk is thrown to the outside of the arc through which it is traveling. Of two liquids whirling through the same arc, the greater force is exerted by the one of greater specific gravity. The serum, therefore, is forced to the outside of the fat in the bowl, causing the formation of two layers, one of serum, and, inside of that, one of closely crowded fat globules interspersed with some serum. Separation is completed by leading these two layers from the bowl through different outlets.

Gravity Creaming. Early dairying was entirely a farm enterprise, and no one knows when gravity creaming was first practiced. The rising of cream on milk is so certain to occur whenever milk is allowed to stand that it must have been known for a long time. Early writers agree that the so-called "shallow-setting method" was the first of several gravity methods practiced. This method gave way to the deep-setting method, which, in several of its variations, was in general use until the centrifugal separator was developed. Gravity creaming by the use of both the shallow pan and the deep-setting systems still is practiced where small quantities of milk are produced or the conditions of butter making still are quite primitive.

The Shallow-pan System. The practice of placing milk in shallow, rather than deep, dishes when cream was desired undoubtedly was based upon experience. During the years when this system came into use, few homes were equipped to furnish cooling facilities. If warm milk is placed in a deep container, cream will rise, to be sure, but the separation is less complete than is the case when milk layer is not over 2 inches deep. The type of vessel used in America for this system of creaming is a tinned metal pan about 4 inches deep. The shallow-pan system is still used to a limited extent where small quantities of milk are produced or where agriculture is conducted in a primitive way. The milk is poured into the pans immediately after milking without cooling and the pans are placed preferably in a moderate temperature, for example in a cellar or basement. The skimming is done at the end of 24 to 36 hours, at which time the milk below the cream usually is coagulated. The cream is removed with a tin "skimmer," an appliance in the form of a shallow flat dish.

The shallow pan served a useful purpose at a time when quality of product was less important than now and losses of milk fat were of little significance. As the milk usually is soured to the point of coagulation before skimming takes place, it is evident that the cream secured will not be sweet. For this reason, it is unsuited for table use. Butter made from such cream may be, at times, of fair quality but often is quite the reverse. The manufacture of high-class butter requires some control of the fermentations of the cream by the butter maker. With cream from shallow pans, no control was possible.

Another serious objection to the shallow-pan system was the condition of the skim milk. For pig feeding, the sour condition was not especially objectionable, but for calf raising this condition was a rather serious matter. One strong argument for the introduction of the farm separator was the better quality of the skim milk for feeding purposes.

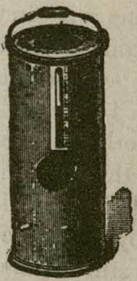


FIG. 30. Can used in the deep-setting process of creaming. This can would be set in cold water 12 or 24 hours before skimming. The cream line may be seen through the glass-covered slot.

Another serious objection is the inefficiency of the shallow pan in recovering the fat in the cream. Skim milk from the shallow pan system contains from 0.5 to 1.5 per cent of fat. If the milk contained 4 per cent fat, a skim-milk test of 0.80 fat is equal to a loss of 20 per cent of the total fat. The fat produced by one cow out of each five is lost in the skim milk. A system with such a low efficiency will not long remain in use when the prices of milk fat reach the levels of recent years and much more efficient methods of getting the cream are available.

The Deep-setting Method. This method seems to have originated in Orange County, New York, probably earlier than 1850. In the Orange County system the milk was set in cans about 20 inches deep and 8 to 15 inches in diameter, and placed in running spring water which was usually at a temperature of 48 to 50°F. (8.9 to 10°C.). In the later improved forms, glass strips were inserted in the wall of the can, one near the bottom and the other near the top. Through these the cream could be observed. The skimming of the cream at first was done by the use of a small conical dipper with a long handle. By means of this dipper, the cream was skimmed from the top of the milk. In the improved form, a faucet was placed near the bottom of the can and the skim milk drawn off until the lower edge of the cream layer could be observed through the glass strip to be approaching the faucet. The cream was then drawn into the cream can. The success of such a method was doubted by many users of the shallow-setting method because of the old belief that fat could not rise more than 2 or 3 inches through milk, but demonstrations soon convinced those interested that the deep-setting method was an improvement on that of shallow setting. The low temperatures at which creaming took place not only insured a more efficient removal of fat from the skim milk, but also greatly retarded microbial action, resulting in the production of a better quality of product than could be obtained by shallow setting.

The deep-setting method was soon adopted in northern Europe where ice water was generally used when cold spring water was not available. After this change the system gained favor rapidly, and, to a large extent, superseded the shallow-setting system.

Efficiency of the Deep-setting System. Fewer criticisms may be made of the deep than of the shallow-setting system, although not all the objectionable features were removed. One objection was the low fat content of the cream. It was not practical to obtain more than 20 or 22 per cent of fat, which resulted in larger losses in the buttermilk than is the case when richer cream is churned. The deep-setting method has the added disadvantage of requiring ice or very cold water, neither of which is available everywhere. The fat loss in the skim milk from deep setting is considerably less than from the shallow pan, amounting to between 0.2 and 0.4 per cent under optimum conditions. This comparatively low loss is obtained only by the use of low temperatures. Babcock, in an early experiment at Wisconsin, demonstrated that the fat content of the skim milk was 0 287 when creaming occurred at 48°F. (8.9°C.), but at 54 to 56°F. (12.2 to 13.3°C.) the fat content was increased to 0.746. It is doubtful if many farmers were sufficiently careful to maintain temperatures as low as 48°F. (8.9°C.) during creaming, and it is probable that when this system was common the fat losses were higher under average conditions than they were believed to be. A loss of 0.4 per cent, which is probably a fair figure for general conditions, means 10 per cent of the total fat produced is lost in the skim milk, or the fat produced by one cow out of ten goes into the skim milk.

The quality of the cream from the deep setting, except in regard to the low fat content, is decidedly better than that from the shallow pan and may be nearly equal to cream from the centrifugal separator. The skim milk is also much better for feeding purposes. The deep-setting system cannot compete with the cream separator, however, and is now used only in a limited way. Numerous patented devices for creaming milk by the deep-setting plan were placed on the market between 1865 and 1890. These did not concern the system itself but consisted of more convenient arrangements for handling milk by this process. Some were in the form of mechanical arrangements for lifting the milk cans from the water, others, special devices for drawing the cream, or fancy cabinet creamers which contained the milk in one compartment with storage facilities for perishable food in another compartment. The best known among these were the Cooley and the Stoddard creamers.

The Water-dilution Method. The so-called "dilution method" was founded on the supposition that the addition of water to milk would lower the viscosity so that the cream could rise more readily. A special tank fitted at the bottom with a drain faucet, above which was a strip of glass giving a view of the contents of the tank, was commonly used. Milk to be separated was placed in such a tank and a quantity of water about equal to that of the milk was added. After about 12 hours, the skim milk-water mixture was drained through the faucet until the cream was seen nearly to reach the drain. The cream then was caught in a separate container.

This method failed to accomplish the desired results. The separation of fat was not so complete as in the preceding methods. The skim-milk–water mixture contained 0.4 per cent fat, or more, making the fat content 0.8 to 1.0 per cent on the basis of skim milk to which no water was added. Skim milk watered in this manner was neither so palatable nor so valuable for food as ordinary skim milk. The well water often introduced organisms that caused undesirable changes in the milk and the cream. Added to these disadvantages was the excessive amount of liquid that required handling. As the cream was drawn within 12 hours or less, however, it was in better condition than that from the shallow pan. Various types of apparatus for using the dilution method were advertised extensively under the name "Dilution Cream Separators" during the early period of the farm separator, from 1890 to 1905. By taking advantage of the publicity the centrifugal separator had received, a large number of these inefficient devices were sold during this period.

CENTRIFUGAL CREAMING

Early Development of Centrifugal Separation. The first application of centrifugal force in removing fat from milk seems to have been made in 1859, when Fuchs, of Germany, whirled milk in test tubes. He, however, was interested in this method as a means of determining the fat content of milk, not as a means of creaming. His work was followed, in 1860, with a similar study by Fesca of Berlin. The first attempt to substitute centrifugal force for gravity in the creaming of milk was made by Prandtl, of Munich, Germany, in 1864. Prandtl's machine consisted simply of a vertical axis capable of being rotated, on which was mounted a crossbar carrying a bucket at each end. The milk was placed in these buckets and subjected to vigorous rotation, after which the machine was stopped and the cream skimmed off. In 1870, Bond, of Massachusetts, attached two glass jars on a spindle which could be revolved at 200 r.p.m. By this means, he secured cream from milk within a few minutes. In 1873, Jensen, of Denmark, had a somewhat similar device revolving two buckets at 400 r.p.m.

An advance toward the development of the modern machine was contributed by Moser, of Austria, in 1872, who exhibited his machine at a Dairy Exposition in that year. Instead of whirling the milk in buckets, Moser used hollow cylinders which were revolved on their own vertical axes. This device was improved and enlarged in 1874 by Lefeldt, of Germany, with a view to adapting it for use in creameries. He used a large drum revolving 800 r.p.m. To operate this machine 220 pounds of milk were placed in the drum and full speed attained in 5 to 10 minutes. It required 20 or 30 minutes to effect complete separation after full speed was gained, and 25 or 30 minutes more for the drum to stop rotating. When the milk has resumed its horizontal position, the cream floated in a heavy layer on top.

The skim milk was removed with a siphon and the cream through a valve at the bottom.

Lefeldt seems to have provided the next advance in 1877 when he devised a tube which removed the cream while the machine was in motion. This was accomplished by introducing the tube in such a position that it would remove the cream as it crowded toward the center of the drum. The skim milk, however, could not be removed while the machine was in motion.

The first continuous separator is said to have been invented by Prandtl in 1875, but this device was not adopted for practical use. Fleischmann, noted dairy scientist of Germany, states that continuous separators of practical importance appeared almost simultaneously in Sweden, Denmark, and Germany in 1879. In an earlier edition of his book, however, he indicates that continuous separators were brought out in Denmark in 1878, by both Winstrup and Nielsen. These machines were doubtless the forerunners of the Danish-Weston separator, which was long in use in Denmark. Other literature states that De Laval's machine, referred to by Fleischmann as the one appearing in Sweden, was placed on the market in 1878. It is doubtful if any one person may be credited with being the first to invent a continuously operating separator. It is certain that the experiments of Prandtl, Moser, and Lefeldt were important contributions to the invention, and while due credit should be accorded the inventors of the successful machines, it must be recognized that their machines were the result of combining the earlier ideas of pioneers in the same field, and adding certain features necessary to make the machines practical.

The early separators were hollow-bowl machines. The next material advance in construction was made by the De Laval company, and consisted of adding inside fixtures, or discs, to the bowls. These were known as the "Alpha discs," and the first De Laval machines equipped with these discs were known as the "Alfa Laval." This improvement, coming in 1890 or 1891, increased the efficiency of separation, and, at the same time, permitted reduction in the size of the bowl without interfering with the capacity of the machines. Since that time, various minor improvements have been made, but the present-day machines are built to operate on the principles recognized by the early workers already mentioned. Indeed, modern separators almost universally embody the principle in the design of the De Laval machine of 1891.

Introduction in United States. The first centrifugal separators were of the large-capacity, power type, many of which were in use in the United States within a few years after their invention. Their use supplanted a system of gathering gravity-raised cream. Under the centrifugal system all the farmers delivered their milk either to the creamery or a skimming station and waited in turn for their skim milk which was taken home to be used for feeding livestock. About 1892, the hand separator was placed on the market by the De Laval and several other organizations, and there followed a period during which these machines were tested by various experiment stations with the result that they were recommended over gravity systems and gradually their use was extended. Their adoption by the majority of farmers developed slowly, however, and it was not until after 1900 that they found favor with farmers and not until 1910 that they became very widely used. One of the factors in this development was the encouragement of certain centralizer creamery organizations, who even went so far as to buy the hand separators in carload lots to sell to cream producers in their territory.

The adoption of the hand separator caused a return to the gathered-cream system. Again the skim milk was kept on the farm, and the cream sold as had been done when the gravity-creaming system was employed. This had the advantage of keeping the skim milk at home and avoiding mixing it with the neighbors' skim milk at the skimming station. In this manner, the spread of animal diseases through skim milk was avoided in territories where the skim milk had not been pasteurized before it was returned.

At the present time, a slow change toward the factory skimming of milk can be observed. Many new plants in the West and Middle West, being equipped for the shipment of sweet cream to the eastern markets, are planning to receive milk and do the skimming at the plant, because a better quality of cream usually can be obtained in this way. It is possible that local creameries also may return to the factory-skimming system, as economic conditions make it increasingly necessary to market all of the constituents of milk in place of the fat only, which is the common practice now.

How Centrifugal Separation Is Accomplished. A knowledge of how centrifugal separation takes place may best be gained by following the course of the milk through a separator bowl which is operating normally. As milk enters a rapidly revolving bowl it is acted upon both by gravity and by the centrifugal force generated by rotation. The centrifugal force is so much greater than that of gravity that the effect of the latter becomes negligible. In consequence, milk entering the bowl is thrown to the outer wall of the bowl rather than to the bottom. This means that the bowl fills from the outside toward the center, rather than from the bottom toward the top as it would if gravity were the only force to which the milk is subjected.

The milk entering the rapidly revolving bowl is subjected at once to a very powerful centrifugal force. The milk serum has a higher specific gravity than the fat and, for this reason, is brought to the outer part of the bowl while the cream is forced toward the center of the bowl. The contrast with gravity creaming should be noted. In one case, the force of gravity causes a slow separation of the fat globules from the heavier skim milk, in the other, centrifugal force developed many times greater than gravity results in a rapid and more complete separation of the fat globules.

Construction of the Centrifugal Separator. The modern cream separator consists of a bowl which can be rotated at high speed by means of suitable gears, and arrangements for supplying milk to the bowl and removing the cream and skim milk. A typical construction is shown in Fig. 31. The chief parts of the bowl are the shell, the inside fixtures, and the spindle which supports the weight and, by means of which, the rotation is accomplished. The first separators were hollow bowls, but later greatly increased efficiency was found to be possible through the introduction of various devices inside the bowl of which the most widely used is the disc shown in Fig. 32. The remainder of the machine is essentially a set of gears so arranged as to make possible the turning of the spindle on which the bowl is carried at a high rate of speed. The gears are commonly housed in a tight case in which they dip in the oil while operating. When the bowl is supported from the bottom as is most common, two bearings are necessary, one to support the weight, and the second to maintain the upright position. These bearings must be

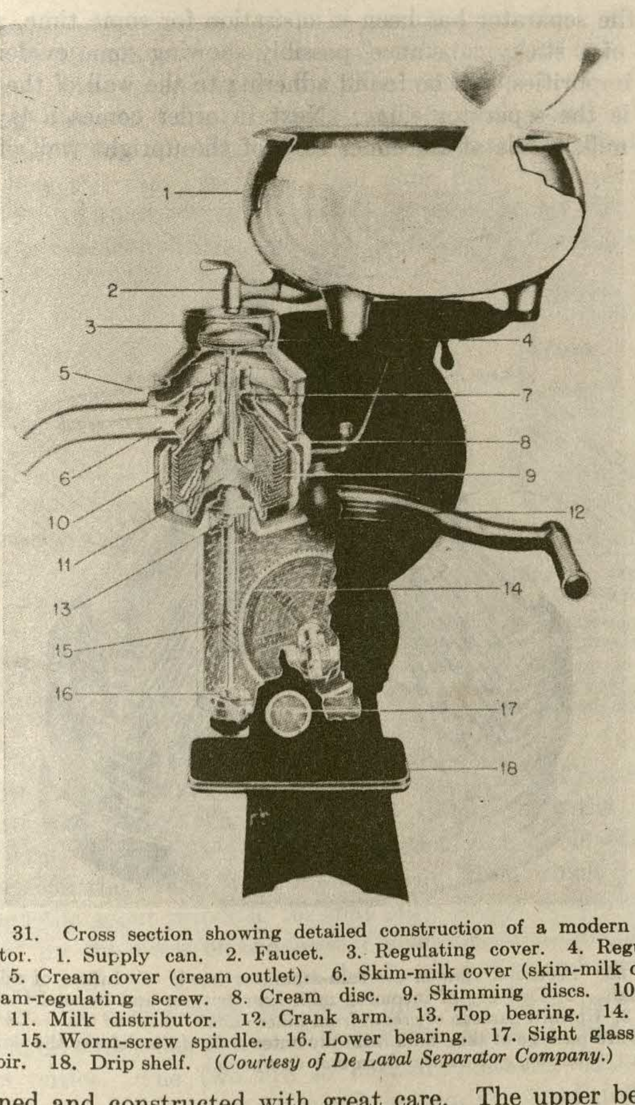


FIG. 31. Cross section showing detailed construction of a modern cream separator. 1. Supply can. 2. Faucet. 3. Regulating cover. 4. Regulating float. 5. Cream cover (cream outlet). 6. Skim-milk cover (skim-milk outlet). 7. Cream-regulating screw. 8. Cream disc. 9. Skimming discs. 10. Bowl shell. 11. Milk distributor. 12. Crank arm. 13. Top bearing. 14. Worm wheel. 15. Worm-screw spindle. 16. Lower bearing. 17. Sight glass in oil reservoir. 18. Drip shelf. (*Courtesy of De Laval Separator Company.*)

designed and constructed with great care. The upper bearing is generally fitted inside a spring in order that the bearing may adjust itself and maintain the bowl in an upright condition even though the frame of the machine is not exactly level. In a few models the bowl is suspended which makes necessary the use of only one bearing and insures the freedom of the bowl at all times to operate in a perpendicular position.

If the separator has been in operation for some time, a thin layer of a sticky substance, possibly showing some evidence of solid impurities, will be found adhering to the wall of the bowl. This is the separator slime. Next in order comes a layer of skim milk, while at the inner edge of the upright wall of fluid the fat globules are packed closely together forming cream. This gathering of the cream near the center of the bowl is the first and most important step in centrifugal separation. All that remains is to lead the two layers out of the bowl without remixing. The separate removal of these two layers is accomplished by establishing two outlets at proper distances from the axis of the

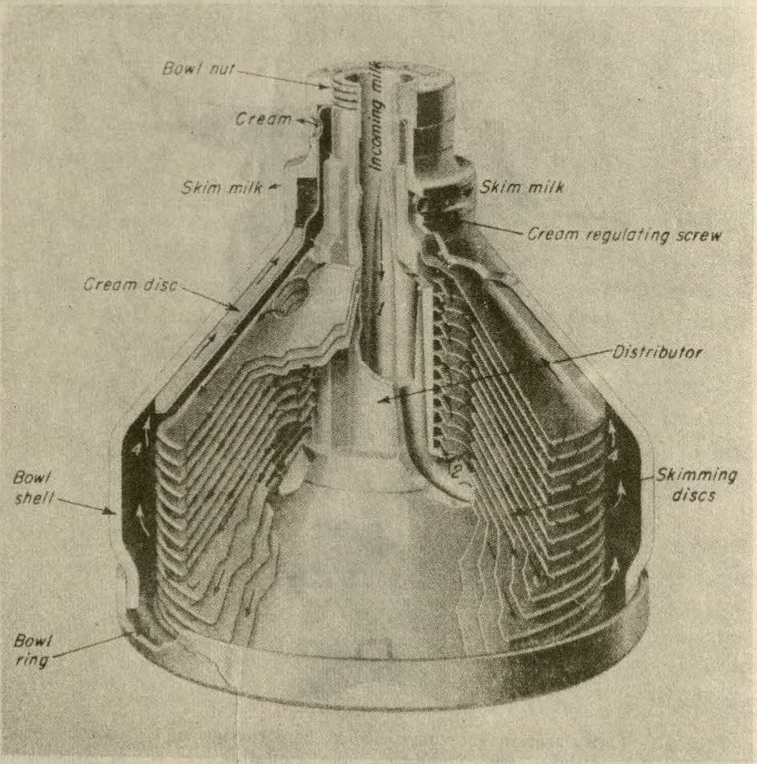


FIG. 32. Sectional view of a cream-separator bowl. 1. Inflow of milk into feed shaft. 2. Delivery of incoming milk near bottom and beyond the cream wall. 3. Upward passage of cream from inner ends of discs to the cream outlet. 4. Upward passage of skim milk from the outer ends of the discs to the skim-milk outlets. (*Courtesy of De Laval Separator Company.*)

bowl, one of which connects with the cream layer in the bowl, the other with the outer edge of the bowl where the skim milk with the lowest fat content is found. The connection between the skim-milk layer and the skim-milk outlet is made possible by a device called the "dividing disc." The diagram, Fig. 33, illustrates how this disc functions. The skim milk from near the outer edge of the bowl cavity moves between the dividing disc and the inside shell of the bowl. At the top of the disc the space between it and the shell of the bowl connects with a slot in the neck of the bowl. This slot is the skim-milk outlet. The skim milk which comes from the outlet with some force is gathered in the so-called "skim-milk pan" from which it flows through the spout provided for that purpose. A second outlet, located on the neck of the bowl above the skim-milk outlet, connects with the inner side of the dividing disc and serves to conduct the cream from the bowl into the cream pan. The skim-milk outlet has a capacity much in excess of that of the cream outlet. The two are so located, however, that when the separator is receiving a normal, or nearly normal, inflow of milk a portion will discharge from each outlet. The cream outlet opens from a point slightly nearer the axis of the bowl than does the skim-milk opening and the cream, therefore, is subjected to less centrifugal force at the point of removal than is the skim milk. As a result of its location and capacity the

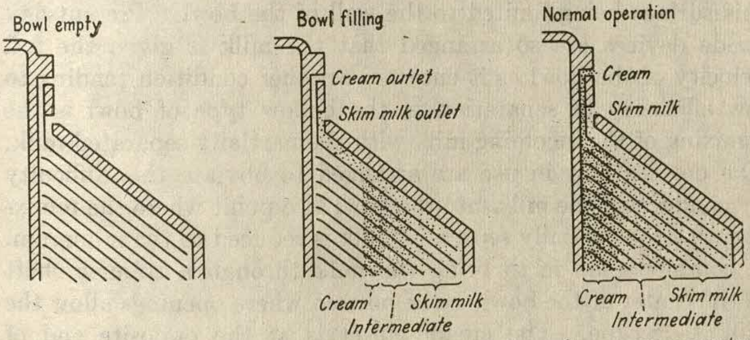


FIG. 33. Diagrammatic cross section of one-quarter of a cream-separator bowl illustrating the filling of the bowl. The filling occurs from the outside toward the center, not from the bottom upward. The center illustration shows a bowl partly full. The cream wall is already forming. When the bowl is full, as shown on the right, the cream and skim milk discharge through separate outlets.

skim-milk outlet removes from 75 to 90 per cent of the total inflow, the remainder coming from the cream outlet.

Inside Fixtures. As mentioned the earlier separator bowls were hollow. Later, it was found that the capacity and efficiency could be greatly increased by the use of devices to go inside the bowl. In the hollow bowl the incoming milk did not acquire, immediately, the speed of the rotating bowl on account of the relatively small surface with which it came into contact, this surface being limited to the wall of the bowl. Present-day inside devices are so arranged that the milk is given the full velocity of the bowl as it enters. Another condition tending to low efficiency of separation in the hollow type of bowl is the remixing of the incoming milk with the partially separated milk. The devices now in use are arranged to obviate this difficulty by conducting the milk into the bowl at a point where the remixing with the partially separated milk is reduced to the minimum. A common plan is to bring the milk through a tubular shaft in the center of the bowl to the bottom where openings allow the milk to escape. The cream outlet is at the opposite end of the bowl where the incoming milk does not cause remixing of the cream and skim milk.

Control of Richness of the Cream. Every cream separator is equipped with a device for regulating the fat content of the cream. This consists of a means for moving either the cream or the skim-milk outlet toward or farther from the axis of the bowl, or for closing off a part of the opening at the same time that it is moved nearer the center. This device, when attached to the cream opening is known as a "cream screw," and when attached to the skim-milk opening, is known as a "skim-milk screw." When the cream screw is moved nearer to the center of the bowl, the centrifugal force operating at this outlet is decreased, due to a reduction in the circle through which it whirls. At the same time, the opening is moved nearer to the inside of the wall of liquid being centrifuged. It is clear that such a change will cause a reduction in the amount of liquid flowing through the cream outlet, and an increase in volume of the liquid flowing through the skim-milk outlet. In effect, the moving of a cream screw toward the center of the bowl causes a part of the serum, which would otherwise have gone with the fat as cream, to be diverted to the skim-milk outlet and a higher testing cream results. The skim-milk screw also produces changes in the percentage of fat of the cream by changing the ratio of cream to skim milk, but, in this case, a lower testing cream results when it is moved nearer to the center because by so doing, the amount of skim milk delivered through the skim-milk outlet is reduced, and the amount of cream increased by the added skim milk diverted to the cream outlet.

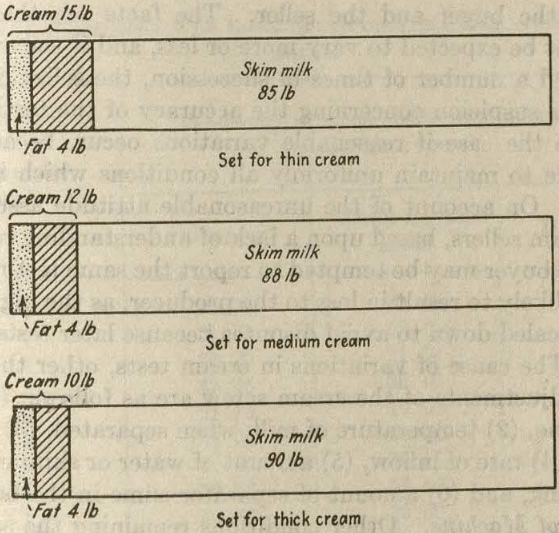


FIG. 34. Graphic illustration of the effect of changing the cream screw. The graph represents 100 pounds of whole milk containing 4 per cent fat. When set for thin cream, the same amount of fat is in the cream as when set for thick cream, but the volume of the cream is greater because more of the milk serum (skim milk) is taken with the fat. The efficiency of separation is not materially affected by the adjustment of the cream screw.

In this way, the fat percentage of the cream may be varied within quite wide limits without any effect upon the efficiency of fat recovery. To illustrate, let it be assumed 100 pounds of 4 per cent milk is separated, resulting in 85 pounds of skim milk and 15 pounds of cream. Ignoring the small loss of fat in the skim milk, the cream will have a fat percentage of 26.66. If the cream screw is now moved nearer the center and another 100 pounds of the same milk separated, the portion recovered as skim milk may be 88 pounds, as cream, 12 pounds. In this case, the cream contains 33.33 per cent fat. Both lots of cream contain, however, the same quantity of fat.

Factors Governing the Fat Percentage. It is commonly known that the fat percentage of machine-skimmed cream can be varied by changing the position of the cream screw. The fact that there are at least six other factors which cause variations in fat content of cream is not so commonly known. The separator user too often has assumed that any variation in his cream test as made by the cream buyer is evidence of careless or dishonest practices. Disputes of this nature are only too common between the buyer and the seller. The facts are that cream tests must be expected to vary more or less, and if the same test is reported a number of times in succession, the seller has more reason for suspicion concerning the accuracy of the testing than would be the case if reasonable variations occur, because it is impossible to maintain uniformly all conditions which influence the test. On account of the unreasonable attitude assumed by some cream sellers, based upon a lack of understanding regarding tests, the buyer may be tempted to report the same test regularly which is likely to result in loss to the producer, as the higher tests may be scaled down to avoid disputes because later tests may be lower. The cause of variations in cream tests, other than those due to adjustments of the cream screw are as follows: (1) speed of machine, (2) temperature of milk when separated, (3) richness of milk, (4) rate of inflow, (5) amount of water or skim milk used for flushing, and (6) amount of separator slime in the bowl.

Speed of Machine. Other conditions remaining the same, the higher the speed the richer the cream. Table IX gives results obtained by the authors with five separators concerning this factor. It is clear from the table that as the speed increases the fat percentage in the cream increases. It should be noted that the effect of speed is more pronounced when the cream screw is adjusted to deliver cream high in fat percentage. This relation of speed to richness of the cream necessarily must be the result of a change in the proportion of cream to skim milk as the speed changes. It should be kept in mind that the milk intake remains essentially the same under all conditions of operation.

As the speed of the bowl is increased, the centrifugal force applied to both the cream and skim milk within the bowl is necessarily increased. Centrifugal force varies not with the velocity, however, but as the square of the velocity. The skim milk, being farther from the center of the bowl, revolves through a greater arc or at a greater velocity than does the cream. The increase in speed, therefore, has a more pronounced effect upon the skim milk than upon the cream, and the outflowing skim milk moves at a greater velocity through the opening. This increased speed results in a greater total quantity passing out of the skim-milk opening. This inevitably decreases the amount of cream which means a higher fat percentage.

Table IX. The Effect of Bowl Speed on the Percentage of Fat in Cream

Separator number	Percentage of fat in cream from operation at different speeds		
	Full speed	Three-fourths speed	Half speed
1	20.00	20.40	17.50
1	51.20	42.40	32.20
2	21.70	21.50	18.20
2	42.35	35.10	22.65
3	21.75	19.95	16.85
3	41.60	29.70	24.00
4	31.30	30.15	28.95
4	39.70	35.50	29.90
5	44.50	22.50	
5	20.00	18.00	

The Temperature of the Milk. When all other factors are kept constant, an increase in the temperature of the milk to be separated causes a decrease in the fat percentage in the cream. Conversely, a decrease in the temperature of the milk causes an increase of the percentage of fat in the cream. This fact is illustrated by Table X.

Occasionally, with certain machines, the separation of milk at extremely low temperatures results in a decrease of fat percentage in the cream rather than the increase that might be expected normally. This is due to the clogging of the bowl with the cold cream which adheres to the inside fixtures of the bowl. This effect usually is featured by a high loss of fat in the skim milk.

The increase in test of the cream when the temperature of the milk decreases is caused by a choking of the cream outlet by the colder, thicker cream. Cold cream does not flow so readily as warm cream, and, therefore, less liquid is permitted to pass through the cream opening when cold. As most of the fat is still delivered through the cream opening the reduction in flow is represented by a corresponding increase in the skim milk diverted to the skim-milk outlet. As the temperature of the milk increases, the fluidity of the cream increases so that a greater flow again may occur through the cream outlet. Inasmuch as this increased flow must be nearly all skim milk, the fat percentage of the cream decreases proportionately.

TABLE X. EFFECT OF TEMPERATURE OF MILK SEPARATED ON FAT PERCENTAGE IN CREAM

Separation trial	Temperature, degrees Fahrenheit	Fat content, percentage
1	120	24.5
	90	30.0
	75	43.0
2	120	43.5
	75	50.7
3	90	21.5
	80	22.0
	70	25.4

Richness of Milk. In the case of most separators the richness of the milk exercises a direct influence upon the fat percentage of cream skimmed from it. The effect is more pronounced with some separators than with others, due to the difference in bowl construction. This relation is illustrated in Table XI, which presents figures from experiments by the authors.

The effect of the fat percentage of the milk upon the richness of the cream is explained by the fact that the separator bowl is so constructed as to deliver from the cream outlet a rather definite proportion of the inflow regardless of the richness of the milk. If the same quantity of cream is secured from two lots of milk having the same weight but different fat contents, it is clear that the cream from the richer milk will contain the more fat. For example, let it be assumed that from 100 pounds of milk containing 3 per cent fat, 15 pounds of cream were separated. If no fat were lost in the skim milk, this cream would have a fat content of 20 per cent. If the milk had contained 4.5 per cent fat, however, the yield of cream would have been essentially the same, that is 15 pounds, but the fat content in this case would be 30 per cent. Some separators do not behave exactly as indicated in this calculation, however, and produce a somewhat larger proportion of cream from rich milk than from milk containing low percentages of fat. For this reason, the increase in the cream test may not be exactly in proportion to the increase in the test of the milk separated.

TABLE XI. EFFECT OF RICHNESS OF MILK ON FAT PERCENTAGE IN CREAM

Separator	Fat percentage	
	Milk	Cream
1	5.0 4.1	20.15 16.85
2	4.8 3.0	40.40 24.60
3	5.2 4.2	48.00 41.75
4	4.8 3.2	40.00 27.00
5	5.4 4.2	29.00 25.00

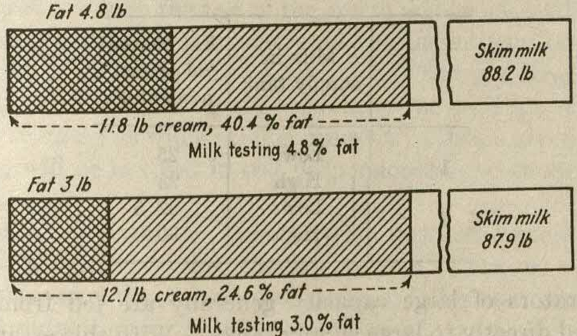


FIG. 35. Graphic illustration of an experiment to study the relation of the fat percentage of the milk separated to the amount of cream and the cream test, Practically the same amount of cream is obtained from milk containing 4.8 per cent fat and from that containing 3 per cent. The cream from the 4.8 per cent milk, therefore, has a much higher fat percentage.

Rate of Inflow. If the rate of inflow of milk into a separator bowl is markedly altered, a change in the fat content of the resulting cream is to be expected. When other conditions remain constant, a reduction of inflow causes an increase in the percentage of fat in the resulting cream. In a trial by one of the authors, milk was fed into a separator as fast as possible by removing the regulating float and maintaining the receiving cup full of milk. The cream had a fat content of 16.3 per cent. The intake then was reduced by regulating the flow of milk to a point which maintained but a small amount in the receiving cup. The cream in the second case contained 20.5 per cent fat. It is clear that the increased fat percentage in the second trial was the result of a smaller total intake of milk. The rate of inflow is not subject to much variation with small-sized separators, because the inflow is regulated by a float in the receiving cup. The rate of inflow will be influenced somewhat by the height of the milk in the supply can. Through the variation in pressure exerted by this means the depth of milk in the supply cup is affected. When it contains a deep layer of milk somewhat more is forced into the bowl than when a small amount is in the container. Two trials by one of the authors gave the following results:

	Milk in supply tank	Fat content of cream, percentage
1	Low	25
	High	23
2	Low	32.5
	High	30.0

Separators of large capacity generally are fed from faucets attached directly to large supply tanks. With this arrangement, variations in the fat content of the cream are frequent and more pronounced than in the case of some machines where a float is used to regulate the intake.

The effect of rate of inflow on the percentage of fat in the cream is explained by a change in the ratio of flow through the cream and the skim-milk openings. A reduction in inflow results in the passage of a greater proportion of the intake through the skim-milk outlet and a smaller proportion through the cream outlet. The reduced proportion of cream is represented by skim milk diverted to the skim-milk outlet, which means that the fat is contained in less cream which is necessarily of a higher test than at the greater inflow. A trial conducted by one of the authors shows the effect of this factor under rather extreme conditions. The inflow of milk was greatly reduced and all other factors kept uniform. The results were as follows:

Rate of flow, pounds per hour	Cream in percentage of total intake	Fat in cream, percentage
956 (normal)	11.39	36
505	9.68	55

Amount of Flushing. It is customary to flush the separator bowl just after the milk has all passed through the machine by allowing water or skim milk to flow into the milk intake. This is done to remove cream lodged within the various parts of the bowl and the cream spout. It is readily understood that the addition of water or skim milk to the cream, which will result during flushing, will lower the percentage of fat in the product. The degree to which the test of the cream will be affected depends upon the amount of cream separated and the amount of water or skim milk, or both, used for flushing. The test of a large amount of cream will not be lowered so much by the addition of a given amount of liquid as will a smaller amount. Also, a given amount of cream will be lowered in test proportionately as more flushing liquid is used.

Formation of Separator Slime. With farm separators slime is rarely a factor in altering the fat content of cream, especially when these machines are washed properly after each separation. A slight reduction in the fat percentage of cream may result if large amounts of milk are separated and the machine is cleaned only after each second operation. The effect is more often noticed with power separators than with hand machines, because power machines often are operated continuously for 4 or 5 hours so that a very thick layer of slime forms on the inside of the bowl shell. When this takes place, the space where the skim milk passes between the dividing disc and shell of the bowl is reduced so that more and more skim milk is diverted to the cream outlet. One of the first indications of this condition is an increase in the size of the stream flowing from the cream spout. The increased flow is, therefore, a signal to stop and clean the bowl.

Variations under Practical Conditions. Cream usually is bought and sold on the basis of the milk fat contained. The cream producer often is much concerned over the variation in the fat percentage from time to time. Sometimes he is inclined to question the accuracy with which the testing is done. He has not changed the cream screw; the same cows and the same feed are in use; and the separator is operated by the same man. With such conditions uniform why should the test vary from 2 to 5 per cent or even more from one delivery to another? The cream test, however, does vary even when the conditions mentioned are uniform. The cause or causes are to be found among those already described. It is impossible, in most cases, for the man who makes the test to explain the cause of the variation because he does not have the necessary facts at hand. On account of a lack of understanding of the subject, often some cause is suggested which only makes the situation more involved. With a proper understanding of the subject, certain facts may be connected with the variations experienced. For example, it is well known that the milk of fresh cows has a lower fat content than that of cows near the end of the milking period. If a certain herd has a large proportion of fresh cows, the test is likely to be lower. In the spring and early summer the milk is, as a rule, lower in fat, due to the seasonal variation described elsewhere, and this may be sufficient to reduce the test materially. At the same time, the warmer weather is responsible for the milk being separated at a higher temperature. Two factors may thus combine to reduce the fat percentage. The idea sometimes advanced that the feed of the cow is responsible for the changes in test is absurd in view of the fact that it is firmly established that the feed has no material effect upon the richness of milk. A sudden variation may be the result of using more water than usual for flushing the bowl. The temperature at which the milk was separated may have varied widely from the usual or the speed of the machine may have been abnormal. When sudden changes of any magnitude occur, the chances are that several factors combined to give the results noted. One of the authors made a test to determine the effect of combining the possible factors. A machine which had been skimming a cream testing 25 per cent fat was used. For one separation, all the conditions except adjustment of the cream screw were controlled to cause an increase in the fat content of the cream; in another separation, conditions for a reduced test were combined. The conditions and results are shown by the following:

Separation	R.p.m.	Skim milk for flushing	Fat percentage in milk	Temperature milk	Rate of inflow	Fat percentage in cream
1	70	1.5 quarts	5.45	80°F.	Low	39.5
2	52	1.5 gallons	3.80	90°F.	High	14.0

The results are striking and show how an extreme effect upon the cream test may be produced without changing the cream screw. Here were established combinations of conditions, all of which exist at times in connection with milk separation. As a result, a separator set to deliver cream with 25 per cent of fat under usual conditions, in one case gave cream testing 39.5 in the other 14.0 per cent fat. It is improbable to be sure, that under practical conditions all of these factors will combine to cause such an extreme variation. It is certain, however, that often a combination of two or more is the explanation of a puzzling variation of considerable magnitude in the test. The authors do not infer that all variations in cream tests as made at the creamery or milk station are to be attributed to the conditions of separation. Accurate sampling and testing of cream are by no means easy tasks, and carelessness more often than dishonesty is responsible for a share of the unexplained changes in fat percentage, as experienced by the cream seller.

Efficiency of the Cream Separator. The efficiency of any separator in removing the fat from the skim-milk portion of milk can be measured by the fat content of the skim milk. A good separator, properly operated, leaves practically no fat in the skim milk. Many machines now in use consistently produce skim milk containing not over 0.01 per cent fat as determined by the Babcock method. Centrifugal separators are now so well constructed that a fat content of more than 0.03 per cent as measured by the Babcock test means that the machine either is mechanically imperfect or is incorrectly operated.

The cream separator is an exceedingly efficient machine. Even under ordinary conditions of operation, fully 99 per cent of the total fat in milk is recovered in the cream. This is in striking contrast to the shallow-pan system with an efficiency as measured by fat recovery of about 80 per cent and the deep-setting system with an efficiency of 90 per cent. These figures will hardly convey to the reader the tremendous economic value of the cream separator to the world. A few applications make possible the full significance of the cream separator in modern dairy practice.

The average cow in the cow-test associations of the United States produces 351 pounds of fat in a year. If the milk of one of the average cows from this group was separated during the year by means of a centrifugal separator, the fat remaining in the skim milk at 50 cents per pound would be worth 17½ cents. If the deep-setting system were used, the fat lost would have a value of $17.55, and if the inefficient shallow-pan system were selected, the fat loss would amount to the sum of $35.10. In 1949, the total butter production of the United States was a little over 1,400,000,000 pounds. Practically all of this was made from cream separated by means of a centrifugal machine. Had the shallow-pan system been used the total would have been reduced fully 280,000,000 pounds; if the deep-setting system had been employed the total would have been about 140,000,000 pounds below the amount actually manufactured. It is a safe statement that the cream separator in the United States saves butter each year that would otherwise be lost to a value of between $200,000,000 and $250,000,000.

Factors Governing the Efficiency of Separation. A number of factors are known to affect the efficiency of separation. The most common causes of inefficiency of separation are, (1) mechanical conditions of machine, (2) low temperature of milk, (3) low speed of bowl, (4) high rate of inflow, (5) clogging of bowl, (6) production of excessively rich cream, and (7) separation of high acid milk.

Mechanical Conditions of Machine. Occasionally, the spindle supports the bowl at such a level that the stream of cream from the cream outlet is split between the cream and the skim-milk pans, thus remixing some of the cream with the skim milk from which is was just separated. This difficulty is corrected by readjusting the height of the spindle, which usually can be done by means of an adjustment at the lower end of the spindle.

Cases have come to the attention of the authors where trouble resulted from an incorrect assembly of parts such as placing the discs wrong side up in the bowl, or, as is possible in at least one machine, operating the machine minus its dividing disc. This difficulty now occurs less frequently than in the earlier days of the cream separator because the modern machines either are made so that they can be assembled in only one way, or the correct position of each part is clearly indicated by its construction. Such errors result in a high loss of fat in the skim milk. Occasionally, the discs become so badly worn that incomplete removal of the skim milk results. This fault may be remedied, in many cases, by adding an extra disc to the bowl. It is important that the separator be set level; otherwise, a vibration of the bowl occurs. This results in incomplete separation. The frame should be fixed firmly to a solid foundation to prevent even the slightest movement of the frame while the bowl is in operation. In setting up the separator the leveling should be done at the particular parts of the frame specified by the manufacturers.

Temperature of the Milk. The temperature of the milk is a factor in the efficiency of separation. Some of the separators as constructed several years ago either clogged completely when the milk was too cold or showed a decided reduction in efficiency. The more modern machines are less subject to the effects of temperature but, as a rule, show a somewhat higher loss of fat in the skim milk, if the temperature of the milk separated is lowered materially. The decreased efficiency at the lower temperature results from the slower movement of the fat through the serum as a result of the increased viscosity of the cold milk. The clogging of a separator which sometimes occurs as the result of cold milk is due to the cream adhering to the bowl parts and moving slowly through the cream outlet.

In order to insure the greatest efficiency in the removal of fat during separation, care should be taken to bring the milk to the machine at a temperature as near 90°F. (32.2°C.) as possible. In dairy plants where large separators are in use some advantages are realized by separating at temperatures as high as 145°F. (62.8°C.). This temperature is often convenient because of previous pasteurization of the milk so that the hot milk may be separated before it is cooled. There is little, if any, lower loss of fat in such skim milk than from separation at 90°F. (32.2°C.). The chief advantage of separation at such high temperatures lies in preventing the extensive growth of microörganisms which occurs when milk is held long at 90°F. (32.2°C.).

Low Speed of Bowl. If the separator bowl is operated at a speed lower than that prescribed by the manufacturer, a loss of fat in skim milk is certain to result unless the milk inflow is reduced correspondingly. It is not difficult to understand why this is true. The speed of the bowl determines the amount of centrifugal force generated, and when the amount of centrifugal force is reduced appreciably, the fat cannot be removed as completely from the skim milk during the time it is traveling through the bowl as when greater force is used. If the rate of inflow of the milk is reduced with the speed, however, the milk traveling through the bowl more slowly is subjected to centrifugal force for a longer time; so that fairly efficient removal of fat from the skim milk is assured until the speed is reduced so noticeably that it would be apparent and corrected by the operator. One separator draws milk into its bowl by suction which is dependent on the speed of the bowl. It, therefore, functions automatically to reduce inflow with speed and, thus to a certain extent, avoids fat losses due to subnormal speed of the bowl. In the majority of separators, however, there is no device for automatic control of the rate of inflow by the speed of the bowl, and care should be exercised to insure correct bowl speed at all times.

The effect of bowl speed on the efficiency of separation is shown by Table XII. These data were taken under conditions where the rate of inflow was not varied appreciably. It is well to bear in mind, however, that the ordinary hand separator automatically increases its inflow slightly at higher speeds because of an increased centrifugal force which increases the output of cream and skim milk at their respective outlets and creates a slightly faster rate of travel through the bowl. This change is not very significant, however, and at the lower speeds the reduction in rate of inflow thus caused is not sufficient to prevent an increased loss of fat in the skim milk.

High Rate of Inflow. If milk travels through a separator bowl too rapidly it is subjected to centrifugal force for so short a time that complete removal of fat from the skim milk is impossible.

The average farm separator includes an inflow-regulating device so arranged that the correct rate of inflow is insured within fairly narrow limits.

This device consists of a feed cup with an opening of a diameter which causes milk to enter the bowl at a constant rate when the level of the milk in the cup is kept the same. The level of the milk in the cup is kept nearly constant by the use of a float which rises against the faucet of the supply tank as the feed cup fills and retards flow into the cup. This arrangement does not insure entirely uniform inflow rate, however, because a greater pressure is exerted on the opening and the float when the supply tank is full than when it is nearly empty. Experiments have demonstrated that the fluctuations of inflow rate in hand separators are not sufficient, ordinarily, to affect the efficiency of separation.

TABLE XII. THE EFFECT OF SPEED OF BOWL ON EFFICIENCY OF SEPARATION

Trial number	Fat lost in skim milk at different speeds, percentage		
	Normal speed	Three-fourths speed	Half speed
1	0.02	0.06	0.31
2	0.03	0.05	0.22
3	0.03	0.10	0.90
4	0.03	0.11	0.70
5	0.02	0.05	0.26
6	0.03	0.14	0.62

Factory-size separators do not have so accurate a means for regulating the inflow and require careful supervision in this respect; otherwise, overfeeding of the bowl may take place with some unnecessary loss of fat in the skim milk.

Clogging of Bowl. During centrifugal separation of milk a gray, sticky mass of material, known as separator slime, gathers on the wall of the bowl. This slime is composed of mucilaginous, nitrogenous material, a normal constituent of milk into which are gathered dirt and bacteria thrown so forcibly against it as to adhere to the walls. As separation continues this wall thickens, and it is possible in time to form a layer of slime thick enough to clog the separator bowl. The first indication of clogging is an increase in the flow of cream.

The efficiency of the separator may be affected to some extent before sufficient slime accumulates actually to clog the machine. The farm separator seldom is operated long enough for clogging to occur from an accumulation of slime. Where large quantities of milk are separated, as in whole-milk creameries, the condition may occur frequently unless the separator is stopped at intervals and the slime removed.

Acidity of Milk. As pointed out elsewhere, unless milk is thoroughly cooled immediately after milking, the bacteria bring about decomposition at once. The most common change is the formation of acid. As soon as an appreciable amount of lactic acid has been formed, the condition of the casein begins to change. Before the milk is sour to the taste small particles of casein are visible under a lens, later a complete precipitation of casein occurs causing the common curdling of sour milk. After the milk has reached the point of curdling, it is clearly impossible to separate the cream. Milk, however, is often separated after a measurable amount of acid has formed. The formation of the acid does not interfere with the separation of the cream so far as the passage of the fat through the skim milk is concerned. If the fermentation of the milk has reached a point where particles of casein are present, however, this constituent will accumulate rapidly in the separator slime, resulting in frequent clogging of the bowl, and some reduction in the efficiency of separation.

The Factory Separator. As was previously stated the factory separator preceded the hand machine or farm separator. The present day farm separator can be purchased with capacities ranging from 75 to 750 pounds of milk per hour. The factory separator is designed to handle from 2,000 to 12,000 pounds of milk per hour. Outstanding improvements in the design or construction of the separator are more frequently found in the machines designed for factory use. In recent years a decided improvement has been introduced in connection with the factory separator. These machines are now built so that no air is permitted to enter the bowl or to come in contact with the milk during separation. The milk is fed to the bowl from the bottom of the machine through a hollow spindle. The milk line leading to the hollow spindle is airtight as are the separator bowl and all fittings conducting the skim milk and cream from the machine. The cream forms in a column at the exact center of the bowl. To remove the cream from the bowl the machine is operated under pressure; thus milk is pumped into the machine and exerts a pressure on the cream column, forcing it from the machine. The per cent of fat in the cream is regulated by adjusting the pressure on the cream outlet. With these machines it is possible to separate cream to contain nearly 80 per cent of milk fat. Since no air enters with the milk as it reaches the separator bowl, there is no foaming of skim milk or cream.

EFFECT OF SEPARATION UPON THE MICROÖRGANISMS IN MILK

When milk is set in shallow or deep pans (as described previously) in order that the cream may rise to the surface, it will be found that a considerable percentage of the microörganisms in the milk pass upward into the cream layer with the fat globules.

This tendency for the microörganisms to gather with the fat near the surface is not the result of a specific gravity below that of the milk serum, but is due to a mechanical action. The microörganisms adhere to the surface of the fat globules and are in this manner carried to the upper layers with the cream.

Centrifugal Separation. In the centrifugal separation of milk the bowl revolves at such a high rate of speed that considerable centrifugal force is exerted on the milk which may contain many microörganisms. Some of these microörganisms are thrown into the separator slime at the walls of the bowl but there does not seem to be any particular selectivity in this action. That is to say, there is no general tendency for certain types of microörganisms to be removed more effectively than others, although there is some evidence that the heavier mold spores, yeasts and larger bacteria, may be quite prominent in the separator slime but not to the exclusion of many other types, even the smallest of the bacteria. The difference in specific gravity between the various microörganisms is scarcely great enough to be a factor. On the other hand, many microörganisms become trapped in the more viscous cream and so attached to the fat globules and appear in considerable numbers in the cream. In practice, it is often found, as a result of this, that cream may have a somewhat higher bacterial count than the skim milk but the difference seldom is striking if the separator itself is not a source of contamination. Actually, large numbers of microörganisms are found in the separator slime in which are present many other substances such as proteins of milk (particles of precipitated casein in the case of abnormal or sour milk), traces of other milk constituents, fibrin, red or white blood corpuscles, body cells (complete or in fragments), and foreign material of many sorts.

Why the Bacterial Count May Be Increased. The fact that cream often shows a higher bacterial "count" than the skim milk, or the whole milk from which it was separated, or that the total bacterial count of skim milk and cream exceeds that of the whole milk, demands a word of explanation. If the separator itself is not source of contamination, the bacterial "content" of the cream and skim milk together cannot be greater than the bacterial "content" of the original whole milk because it is known definitely that the separator slime contains large numbers of bacteria which have been removed during separation.

This distinction between "count" and "content" which is made in the case of separation (and later in clarification) is the difference between an apparent and a real situation. The plate "count" is merely a record of the number of individuals, pairs, chains, or clumps of bacteria or other forms, any one of which may produce a single colony on an agar plate. For example, there might have been in a given portion of the milk before separation 100 individual bacterial cells, 100 pairs, and 100 clumps, which might mean 300 colonies on a plate. Under the action of centrifugal force, half of the individuals might have been thrown to the wall of the bowl, all of the pairs broken up so that half of them (or 100 individuals) were caught in the slime of the bowl, and the hundred clumps, each of which might have contained 10 individuals, were disrupted so that half of the cells remained in the slime. The resulting total plate counts of the cream and the skim milk after separation under these conditions might have shown 650 colonies as compared with 300 before separation.

Disease Bacteria and the Separator. The question sometimes arises as to whether or not disease-producing bacteria are removed from milk by the process of separation. In the case of gravity creaming, it has been found that certain types of pathogenic bacteria actually concentrate in the cream layer. In centrifugal separation some of these disease bacteria but not all of them are cast off in the slime accumulating in the bowl. A considerable proportion of them is distributed in both cream and skim milk, especially the former. Consequently, separation is not a process for increasing the safety of milk from the standpoint of disease-producing types of bacteria.

STRAINING, FILTRATION, AND CLARIFICATION OF MILK

Noticeable quantities of foreign material such as particles of dust, dirt, cinders, feeds, bedding, manure, dandruff, hairs, flies and many other undesirable substances may find their way into milk because of careless handling of milk at the dairy farm. This occurs principally at the time of milking. Other substances may be present in various quantities and not represent contamination from filthy surroundings. Some of the worn-out cells making up the delicate lining of the udder, its ducts, alveoli, etc., may be cast off into the milk. Where inflammation of the udder occurs, much of the cell debris from the affected parts is accompanied by corpuscles, fibrin, and serum from the blood, much of which may escape detection. Many of these foreign substances, which have been mentioned above, usually carry large numbers of bacteria, some of them yeasts and mold spores. The particles that are soluble disappear but leave their burden of microörganisms in the liquid milk. The larger, insoluble portions release many of their bacteria and other forms when they are bathed in the fluid milk.

Straining. The practice of straining milk was introduced to provide a means for removing some of the larger particles of foreign material so that the visible sediment in the milk might be reduced. This straining, in the ordinary sense, is accomplished on the dairy farm by means of miscellaneous pieces of cloth, cotton batting, wire gauze, or specially prepared strainer pads. These materials are able to remove principally the large particles, such as straw, hairs, insects, gross dirt, etc. Much of the filth and cell debris passes through the meshes of the strainer. The microörganisms, body cells, and leucocytes are so small that most of them pass through the strainers without restraint. Particles of dirt deposited on the strainers are washed subsequently by succeeding portions of milk so that their contribution of bacteria, etc., is added to the liquid which passes through. Consequently, the ordinary straining of milk should not be depended upon to remove any considerable number of microorganisms. In fact, strainer cloths that are poorly washed and left unsterilized actually may add bacteria to the milk. The fact remains that ordinary straining does not reduce the bacterial content of milk perceptibly but merely removes some of the gross dirt which might appear as visible sediment in a bottle of milk. Milk should be clean and not require cleaning.

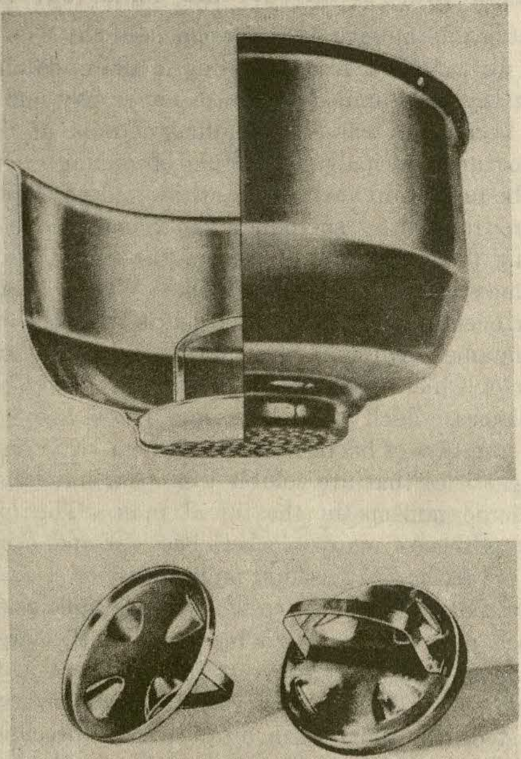


FIG. 36. Strainer commonly used on dairy farms. A cotton filtering disc is held between two metal screens. The assembled strainer is placed over a can and the milk allowed to flow through the cotton disc by gravity. The strainer has a capacity of about 10 quarts. (*Courtesy of Creamery Package Manufacturing Company.*)

Filtration. In order to carry the cleansing of milk a step farther, various devices have been suggested for filtering milk through filters possessing pores much smaller than the ordinary strainer, cloth, or metal. The success attained in filtering water supplies and other liquids has served as a basis for such methods being applied to milk but they have not proved practical. In recent years, milk-filtering devices which are provided with closely woven cotton cloths or cellulose pads have been used. The mesh of these filters is very fine and provides a much more efficient filtering capacity. They are quite widely used in many sections of the country at the present time. In most cases, it is intended that these filter pads should be used but once and then discarded, since their efficiency is impaired or destroyed by washing. They are found to be effective in removing visible sediment from milk but do not filter out the leucocytes, epithelial cells, cell fragments, or microörganisms unless these are trapped on the large particles which make up the visible sediment.

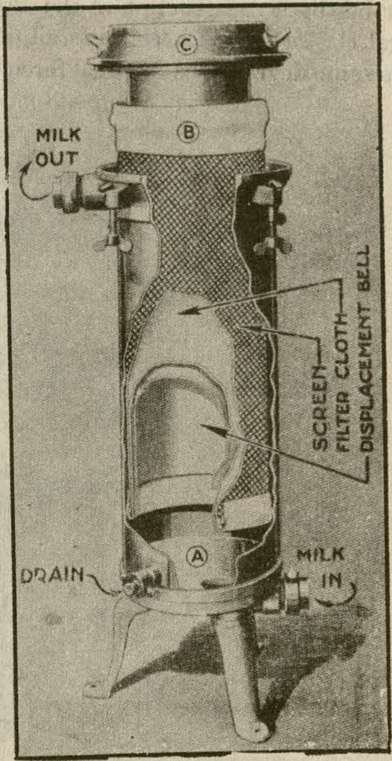


FIG. 37. Cross-sectional view of a horizontal milk filter for use in market-milk plants. The milk is pumped into the filter at the bottom and passes into the chamber on the inside of the cylindrical filter. It is then forced through the filter cloth by the pressure and is discharged at the top of the filter. (*Courtesy of Cherry-Burrell Corporation.*)

Clarification. The accumulation of dirt and slime in the bowl of the centrifugal separator undoubtedly suggested to early users of this machine that it could be used as a means of removing foreign materials from milk. In practice, some difficulties were experienced; the cream and the skim milk did not always mix uniformly; a portion of the milk did not pass close to the periphery of the bowl, which reduced the efficiency; and the space in the bowl for the accumulation of slime was inadequate. As a result, a modified centrifugal separator known as the "centrifugal clarifier" was introduced.

In the centrifugal clarifier, the speed of the bowl is reduced so that little separation of the cream occurs. This is prevented further by a construction of the discs in certain types of centrifugal clarifiers, which compels all of the milk to be subjected to the same degree of centrifugal force by passing near the periphery of the bowl. Furthermore, a greater space outside the discs is permitted for the gathering of the heavier material on the walls of the bowl. Instead of two outlets as in the separator, only one for the unseparated whole milk is provided in the clarifier.

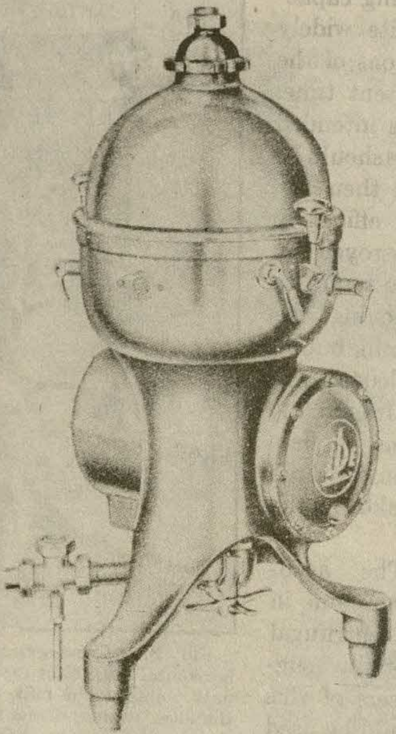


FIG. 38. A centrifugal clarifier. This is a new-type, airtight, foamless clarifier which is very efficient in removing sediment from milk. (*Courtesy of De Laval Separator Company.*)

Efficiency in Removing Sediment. In general, it may be said that the clarifier is the most effective, practical device which is available for improving the quality of milk by removing extraneous foreign material which, unfortunately, may have gained access to the milk during its production and subsequent handling. Due to the fact that most of the dirt, filth, and cell debris present in milk is of higher specific gravity than the milk itself, it is to be expected that a major portion of this foreign material will be thrown out by the clarifier and be collected on the walls of the bowl. The efficiency in removing insoluble dirt is very high. In fact, it is possible to pass through the clarifier milk that has been filtered in the ordinary way and recover in the clarifier slime noticeable quantities of insoluble dirt which has not been removed by filtration. Many of these particles of sediment would be too small to be held back by a filter or to be visible to the naked eye. Milk properly clarified shows no indication of a sediment after standing in a glass bottle.

An examination of the material which is removed by the centrifugal clarifier will reveal a "slime" quite similar to separator slime. It will be found to contain large amounts of actual milk constituents, especially protein substances or particles of precipitated casein, insoluble dirt, and foreign material of all sorts, fibrin, leucocytes, and red blood corpuscles, various cell fragments, and large numbers of microörganisms; in fact anything that readily responds to centrifugal force. The clarifier plays an important role in the removal of cells in homogenized milk to eliminate a troublesome sediment.

Effect upon Bacterial Count. If a bacteriological analysis is made of clarified milk it may be found that the milk has either a higher or a lower bacterial count as determined by the plate method than it did before clarification. Whether the bacterial count will be higher or lower after clarification will depend upon a number of different conditions; but when the clarifier itself is cleaned and well sterilized before use, the *actual numbers* of microörganisms in clarified milk will be considerably lower than in the milk before clarification because it has been demonstrated, as, large numbers of organisms are thrown out into the clarifier slime. When the plate count is higher after clarification, it is only an apparent increase or the clarifier has been improperly cleaned. The explanation for these differences between bacterial "counts" and the bacterial "content" or actual numbers has been given under separation and the same reasons hold for the results obtained during clarification.

The clarifier is not able to remove specific types of bacteria from milk in such a way that it could be depended upon to make milk safer. Some of the disease-producing bacteria may be thrown out into the slime but others may be discharged with the milk. Consequently, clarification is not a health measure in the sense that it removes pathogenic bacteria from milk.

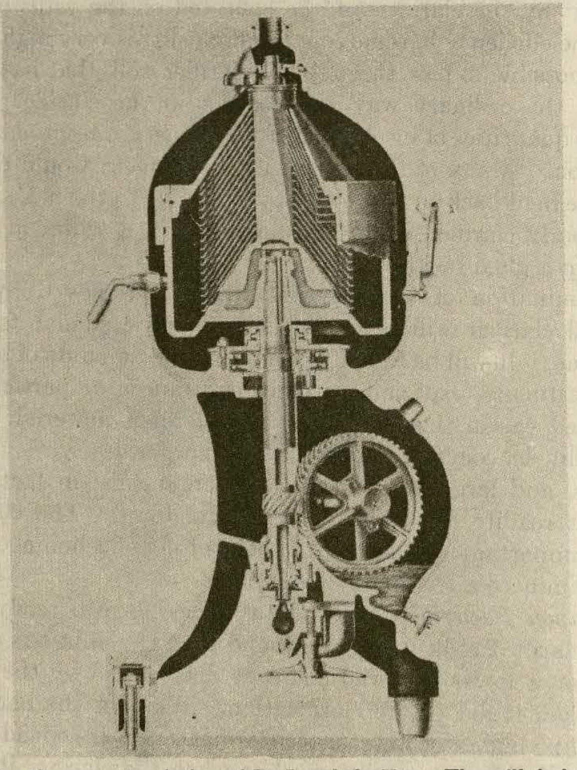


FIG. 39. Cross-sectional view of De Laval clarifier. The milk is fed into the bowl from the bottom through the hollow spindle, under pressure from a pump. The sediment is thrown to the wall of the bowl in the space provided beyond the discs. The milk is discharged from the center of the bowl at the top. (*Courtesy of De Laval Separator Company.*)

Effect upon Keeping Qualities of Milk. Does clarification improve the keeping quality of milk? The answer is, probably not. While results are not always the same, there is a tendency for clarified milk to show slightly poorer keeping quality probably because of the more uniform distribution of the bacteria in the milk. In any case, however, this difference in keeping quality is not sufficiently great to be worth much consideration. The advantage reached by improving the cleanliness of the milk is far more important than the differences in keeping quality.

Effect upon Cream Line. Market milkmen are interested in the effect which clarification may have upon the creaming ability of milk since the housewife is so interested in the cream line. Clarification carried out at temperatures below 90°F. (32.2°C.) has little or no effect on the creaming ability of milk. It would be almost too slight to detect in an ordinary milk bottle. When the temperatures of clarification are higher the cream line may be affected noticeably.

PASTEURIZATION

The preservation of foodstuffs by the application of heat undoubtedly has been practiced as long as fire has been known. Pasteurization derives its name from the eminent French scientist, Louis Pasteur, who during his studies in the years 1860 to 1870 found that heating certain liquids, especially wines, to a high temperature improved their keeping qualities. This process is widely employed in all branches of the dairy industry. In general terms, it is the heating of milk or other dairy products to a temperature which destroys nearly all of the microörganisms present in that product without seriously affecting the composition or properties of the product. It should be followed by immediate cooling of the product to a temperature sufficiently low to check the growth of the microörganisms which are resistant to the temperature used. Pasteurization came into use on a commercial scale in dairy establishments shortly after 1880 in Germany and Denmark. At the present time, it is considered an essential feature in the manufacture of butter and ice cream and in the market-milk industry. It is also spreading rapidly to the cheese industry. The most widely accepted definition for pasteurization, proposed by the U.S. Public Health Service, reads as follows: "The terms 'pasteurization,' 'pasteurized' and similar terms shall be taken to refer to the process of heating every particle of milk or milk products to at least 143°F., and holding at such temperature for at least 30 minutes, or to at least 160°F., and holding at such temperature for at least 15 seconds, in approved and properly operated equipment: . . ."

The practice has become practically universal to attach a recording thermometer to pasteurizing equipment in order that a record may be available of the temperature to which the product has been subjected. In most cities a record of this kind is required for the inspection of the control officials.

Relation of Pasteurization to Microörganisms. Fundamentally, pasteurization is a health measure but actually it is also a commercial expedient. It has been found that a temperature of 143°F. (61.67°C.) maintained for 30 minutes or 160°F. (71.11°C.) for 15 seconds is sufficient to destroy the common disease-producing types of bacteria, such as those of tuberculosis, typhoid fever, scarlet fever, diphtheria, brucellosis, etc., which sometimes are present in milk. Besides, under these conditions approximately 99 per cent of all bacteria are destroyed, as well as most of the yeasts and molds providing the milk does not contain excessive numbers of heat-resistant (thermoduric) types of organisms. By the process of pasteurization, milk is rendered safe and commercially attains a better keeping quality. Pasteurization also provides a substratum in which desirable fermentations can be carried on with greater assurance of success. After the product has been pasteurized, however, all precautions must be taken to prevent recontamination. Furthermore, it must be kept under conditions which will prevent the development of those organisms which have survived. Pasteurization is not a cure-all nor is it foolproof. As much judgement must be exercised in the handling of the pasteurized product as in the case of the raw material.

Methods of Pasteurization. Two general methods of pasteurization are in use. One is known as the "holding" system and the other as the "high-temperature, short-time."

The Holding System. The holding system consists in bringing the milk or cream to a suitable temperature, usually 143°F. (61.67°C.) or higher and holding it at that point for at least 30 minutes followed by rapid cooling. A higher temperature is sometimes used in dairy manufacturing plants, in which case the time of holding may be shortened, for example, 155°F. (68.3°C.) for 20 minutes or 165°F. (73.9°C.) for 15 minutes. A careful control of both temperature and time of heating is important.

The consumer of retail milk usually expects a deep layer of cream to appear in the upper part of the milk bottle with a sharp line of division between the milk and the cream. The use of a temperature much above 144°F. (62.22°C.) causes physical changes in the condition of the milk as a result of which the so-called "cream line" of the milk is reduced and the milk is judged by the consumer to be low in cream content. The holding system is highly efficient in reducing the bacterial content without affecting the cream line seriously.

The High-temperature Short-time System. The machines used are so constructed as to make possible a continuous operation and for this reason sometimes are called "continuous flow" or "flash" pasteurizers. The system depends upon raising the temperature of the milk or cream quickly to at least 160°F. (71.1°C.) and often higher for a few seconds as it passes through the machine. Quick cooling follows.

The flash system is especially applicable to the pasteurization of cream for butter making and temperatures above 160°F. (71.1°C.) are used, for example, 180°F. (82.2°C.). Its chief advantage in creamery operation is the rapidity with which the process is conducted and the smaller expenditure required for equipment necessary to handle a given amount of cream. It is more commonly used in large creameries where one million or more pounds of butter are made annually.

The high-temperature short-time system is now being used more extensively for the treatment of milk or cream designed for direct consumption than it was a few years ago. A few health authorities are not yet convinced that this type of pasteurization can be relied upon to destroy the disease-producing organisms. Another objection raised is that the high temperature employed may exert an appreciable effect on the taste of the milk, giving it a slightly cooked flavor. The cream line, so important in the sale of milk at retail, also was thought to be seriously affected by this type of pasteurization. These latter objections, however, have been overcome in recently designed types of high-temperature short-time pasteurizers especially built for pasteurizing market milk and cream. They operate usually at 160°F. (71.11°C.) for about 15 seconds or longer. Those in use at the present time employ hot water or electricity as the heating medium, and may be either the electric, the so-called "plate," "external-tubular" (surface), or "internal-tubular" types of equipment.

Construction of the Holding Pasteurizers. There are several different types of holding pasteurizers on the market. These machines differ from one another primarily in their shape, general construction, and the method employed in agitating the milk or cream during the heating and cooling process.

Coil Vats. The most common type of holding pasteurizer has been the coil vat. This machine consists of a rectangular or square tank constructed of tinned copper, glass-lined steel, or stainless steel. The sides and the bottom are insulated with cork or other insulating material which is encased in a wooden or a metal covering. A lid of the same construction is provided to cover the entire tank. A coil is suspended lengthwise in the rectangular vat. The coil is usually constructed of the same material as the tank and consists of hollow tubing, 2 to 4 inches in diameter, and encircles spirally a central shaft. The shaft is set on a line representing the center of the tank from end to end. The coiled tubing is placed at a fixed distance from the shaft in

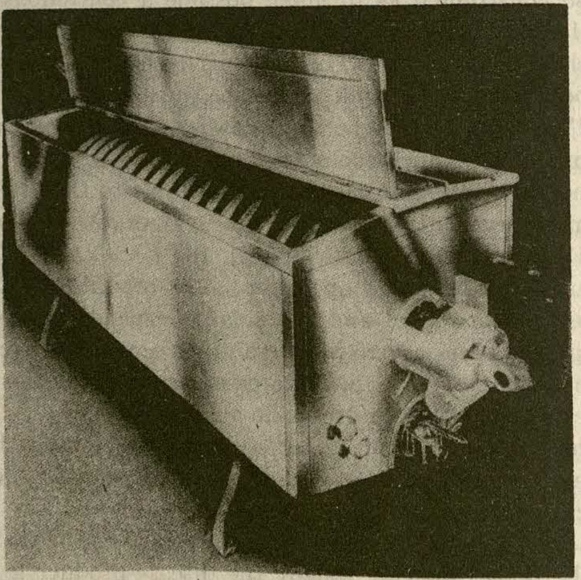


FIG. 40. A horizontal-coil pasteurizer, motor-driven. This type of pasteurizer is used very commonly in creameries and milk plants for the "holding" method of pasteurization. (*Courtesy of Creamery Package Manufacturing Company.*)

such a manner as to carry the coil to a point within 2 or 3 inches of the sides of the tank. The coil is connected directly with the shaft at both ends so that water may enter from the outside of the vat through the shaft, into the coil, and out of the vat through the shaft at the opposite end. By revolving the shaft by means of the power-driven gearing at the end of the pasteurizer, the milk or cream can be agitated and by passing hot or cold water through the coil, the milk or cream may be heated or cooled. A relatively small tank is provided, generally at the end of the vat (it may be a part of the main vat or a separate tank), to hold the water used in heating and cooling. The square type of pasteurizer is constructed in much the same manner as the rectangular vat except that the coil is suspended vertically in the tank.

Glass-lined Tanks. Another type of holding pasteurizer is a kettle-shaped tank constructed of steel, which is enameled with glass on the inside. Surrounding the glass-lined tank is a second tank of steel with an air space between the two. The entire vat is often covered with an insulating material. Milk is agitated in the vat by means of a propeller set at one side and near the bottom of the tank. Milk or cream is heated by passing hot water or live steam into the space between the two tanks. At the same time, the propeller is kept in motion to stir the milk. Cooling is very slow in such tanks and for this reason a surface or tubular cooler generally is used in connection with this type of pasteurizer.

Stainless-steel Tanks. With the development of chromium-nickel-steel alloys, holding tanks have been placed on the market in a great variety of designs. Some type of agitator is suspended from the cover as shown in Fig. 41. The heating or cooling medium circulates in various ways in the space between the outer and inner jackets. The resistance of these alloys to corrosion or attack by dairy products has made them extremely popular in the milk industry in other equipment as well as holders used in the pasteurization process.

Spray Vats. Still another type of holding pasteurizer is known as the "spray pasteurizer." This type of holder usually consists of a long, deep, double-walled tank, the general construction of which, in some instances, is somewhat similar to that of the coil vats. The milk or cream in this type of pasteurizer is agitated very gently by slowly moving paddles which are suspended vertically in the tank containing the milk. Heating or cooling is accomplished in this type of pasteurizer by circulating hot or cold water through spraying devices against the side walls of the inner vat by means of a pump.

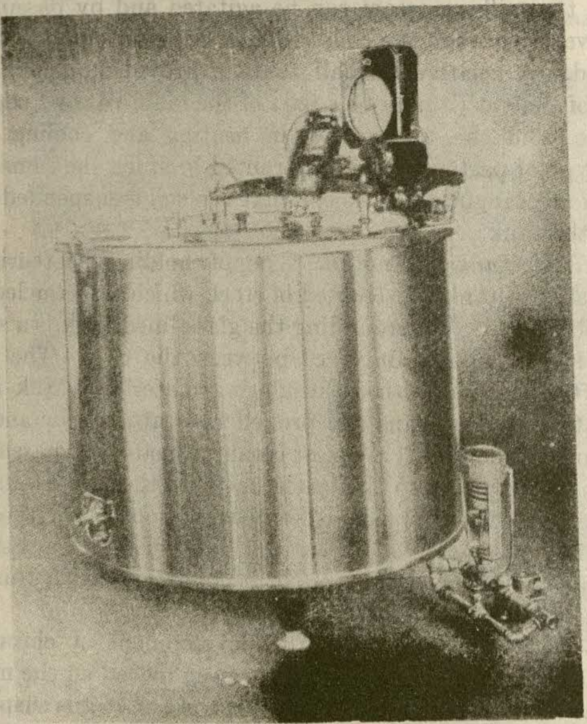


FIG. 41. Stainless-steel-lined and -sheathed milk pasteurizer with recording thermometer and automatic controls. This equipment is used for pasteurizing milk or cream. It represents the "holder" type of pasteurizer. (*Courtesy of The Pfaudler Company.*)

Construction of High-temperature Short-time Pasteurizers. There are several types of high-temperature short-time, flash or continuous pasteurizers on the market. These machines are constructed of heavy copper, tinned copper, or stainless steel. The common types in use are the Danish style, the film type, the internal-tubular or external-tubular (surface), and the plate-type pasteurizers. The latter types are often called "heat exchangers" and may involve regeneration.

The Danish Heater. The Danish heater consists of a double-walled cylinder placed on end, with a height about double the diameter. The milk or cream passes continuously through the inner compartment while the heating medium, live steam or hot water, is allowed to enter the compartment between the two walls. A rapidly revolving paddle keeps the milk or cream in a thin layer against the heated wall of the inner compartment. The time required for a particular portion of milk or cream to pass through the machine varies from a fraction of a minute to not more than 2 minutes. A high temperature is ordinarily employed.

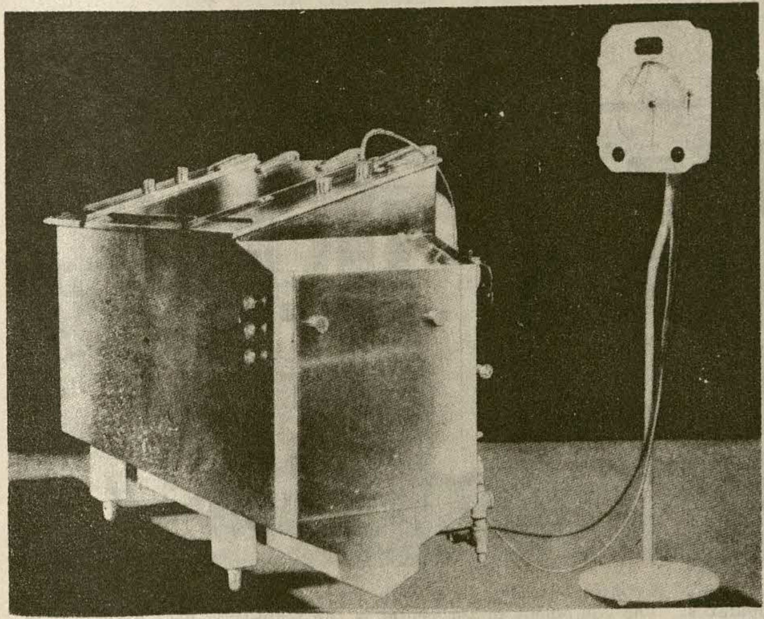


FIG. 42. A spray type of pasteurizer. The spray pasteurizer is provided with slowly moving paddles which keep the milk or cream agitated, while hot or cold water is sprayed in a continuous stream along the side walls of the vat. A recording thermometer and an automatic heat-control attachment are shown. (*Courtesy of Cherry-Burrell Corporation.*)

Drum or Film Heater. This type of flash pasteurizer consists of two drums, one within the other, which are heated by means of steam or hot water. Milk or cream to be heated passes in a thin film between the heated surfaces and thus is raised very quickly to the desired temperature.

Internal-tubular Heater. This consists of a series of two tubes, one within the other. Milk flows through the inner tube while steam or hot water is introduced into the outer tube which surrounds the inner tube. In this manner milk or cream flowing through the inner tube is heated to a desired temperature.

External-tubular (Surface) Heater. This equipment usually involves the passage of milk or cream over the surface of the tubes with the heating medium flowing through the inside of the tube. Either internal-tubular or external-tubular pasteurizers may also serve as regenerators with the milk or cream passing both inside and outside of the tubes but in opposite directions, thus providing for mutual heating and cooling.

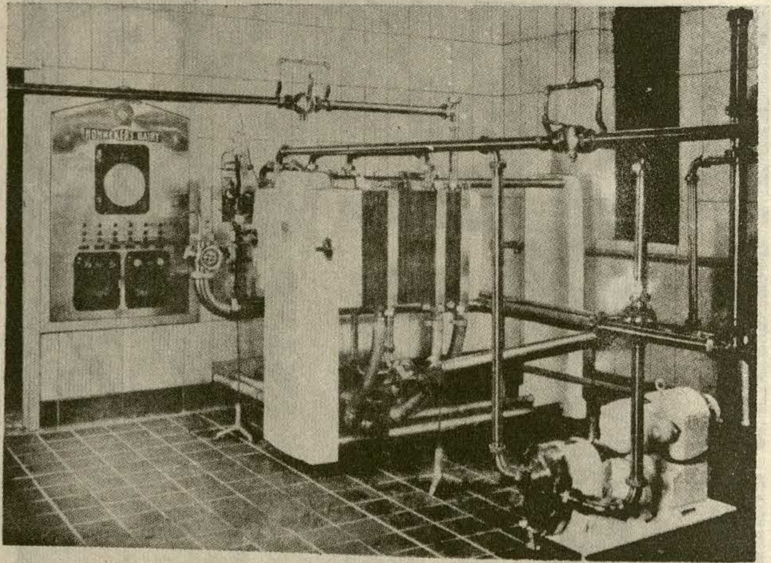


FIG. 43. A continuous, plate-type, high-temperature, short-time pasteurizing apparatus. The equipment in the center is the plate-type heat exchanger or pasteurizer. The milk is heated and cooled within the same unit, and the process is regenerative to increase efficiency of heat exchange. The control panel with heat regulators, recording thermometer, gauges, and switches is located to the left of the pasteurizer. (*Courtesy of Creamery Package Manufacturing Company.*)

Plate-type Pasteurizer. For a number of years the plate type of heat exchanger has been used for heating or cooling liquids. Recently this system has been employed in connection with the pasteurization of milk and cream. European dairies employed these types of flash pasteurizers some time before they were accepted in America.

The plate pasteurizer consists of a compact group of relatively thin metal plates that are held tightly together in a press. The plates are so designed as to permit the flow in opposite directions of milk and water in a thin film between two plates. Milk is brought to the pasteurization temperature in a few seconds. Additional plates permit the cooling of milk very quickly. By adding still more plates a regenerative system is included, which employs hot milk to heat incoming cold milk and cold milk to cool outgoing hot milk, thus making very efficient use of the heat employed in the process. By almost instant heating and cooling, the creaming ability and original flavor of milk are retained.

Cooling Milk or Cream. After milk or cream has been subjected to the temperature of pasteurization, the product generally is cooled by passing it over a surface tubular cooler. Such a cooler consists of a series of hollow tubes constructed of tinned copper, stainless steel, or other metal through which cold water or cold brine may pass and over which the hot milk or cream is allowed to flow in a thin layer. Frequently, the cooler consists of two sections, one set above the other. Cold water is permitted to flow through the upper section and cold brine from a tank of brine, cooled by mechanical refrigeration, is connected with the lower section. By means of such an arrangement milk or cream is cooled very quickly to much lower temperatures than can be accomplished with the water available. Ammonia may be allowed to expand directly into the lower section and thus do away with the use of brine. Internal-tubular coolers, similar to the internal-tubular heaters, also are used in some plants. In the plate-type of pasteurizer the cooling may be accomplished through additional sections of plates acting as coolers.

In-the-bottle Pasteurization. The "in-the-bottle" system of pasteurization is used to a limited extent in the pasteurization of milk and cream for market-milk trade. The system consists of placing bottled milk and cream in a tightly closed chest, some types of which have been constructed of wood, some of steel, and others of concrete. By heating the chest, and by carefully controlling the steam permitted to enter the chest, the milk is heated to the pasteurizing temperature used in the holding method.

Cooling is accomplished very slowly by spraying water, first hot and then cold against the bottles, slowly lowering the temperature so as not to chill the glass bottles too quickly.

Electrical Pasteurization of Milk. The most modern form of electric pasteurizer consists of a regenerative preheater, where the milk is brought to about 120°F. (48.89°C.), and the pasteurizer proper, consisting of a rectangular, vertical chamber 2 feet high and 3 by 4 inches in cross section, with two sides made up of carbon electrodes about 3 inches apart. The milk flows between these electrodes, and the temperature of the milk is raised to 161–163°F. (71.67–72.78°C.) by the resistance offered by the milk to the passage of a 110-volt alternating current. The milk is exposed at this temperature for 15 to 20 seconds, after which it is cooled.

HOMOGENIZATION

The process of making a stable emulsion of milk fat and milk serum by mechanical treatment is termed "homogenization," suggesting that the mixture is homogeneous. The machines used for this purpose are known as "homogenizers." The application of these machines to food products was first made in France, where Paul Marix emulsified the ingredients of margarine. The earliest machine designed for use on milk fat was patented by August Gaulin of Paris, France, in 1899. This homogenizer was introduced in the United States between 1904 and 1905. Since the invention of the Gaulin machine, numerous others built on much the same principle have been introduced. A typical example of such a machine is known as the "viscolizer."

Types of Homogenizers. There are on the market three distinct types of homogenizers. These may be generally classified as the (1) high-pressure type, (2) the low-pressure–rotary type, and (3) the sonic vibrator.

1. *High-pressure Homogenizers.* In general, the high-pressure homogenizers on the market consist of a single-acting triplex pump with each cylinder having a suction and discharge valve. The discharge valve of each pump empties into a common discharge pipe, in which is placed a special valve. This valve is similar to a safety or release valve and so constructed that the operator of the machine may vary the pressure required to force a liquid through it. It is the construction of this valve that

accounts for the chief difference between different makes of high-pressure homogenizers. One of these machines is equipped with two valves, commonly designated as a "two-stage valve" homogenizer, which makes it possible to operate the machine at two different pressures.

These machines function by forcing the milk fat under pressure through a very small orifice with the result that the fat globules are broken apart and remain dispersed in a stable emulsion in the milk serum.

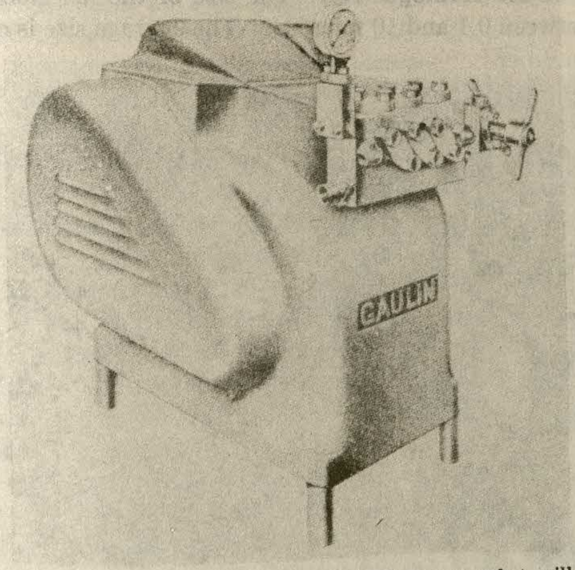


FIG. 44. Homogenizer. Milk or cream intended for market milk or cream may be passed through the homogenizer when it is desired that the milk fat remain in a more permanent emulsion. When the mixture used in making ice cream is passed through the homogenizer, the finished ice cream has a smoother and more velvety texture. (*Courtesy of Manton-Gaulin Manufacturing Company.*)

2. *Low-pressure–Rotary-type Homogenizer.* It is not easy to give a general description of the construction of the low-pressure–rotary-type homogenizers as they differ very materially in design. They are so constructed that they subject milk fat to a grinding and shearing action under low pressure. High-pressure homogenizers may be operated at pressures ranging from 500 to 5,000 pounds per square inch but the low-pressure–rotary type is usually operated at pressures below 500 pounds. The action on

the fat globules is effective, but it is doubtful if the shattered fat globules are as small as those obtained by the high-pressure machines.

3. *Sonic Vibrator.* A recent development in the process of homogenization involves the subjection of milk to high-frequency vibrations in a device called a sonic vibrator or oscillator. The machine is not widely used in the dairy industry at present, but its use may increase.

Action of the Homogenizer. The size of the fat globules in milk is between 0.1 and 10 microns. The average size is close to 4 to 6 microns. When milk or cream is passed through the homogenizer, there is a decided reduction in the size of the fat globules. Most of them are reduced to 2 microns or less. Naturally, the number of individual globules is increased several hundred times. No cream line is formed on milk after homogenization nor will butter granules be produced from homogenized cream by churning. Furthermore, there is an increase in the

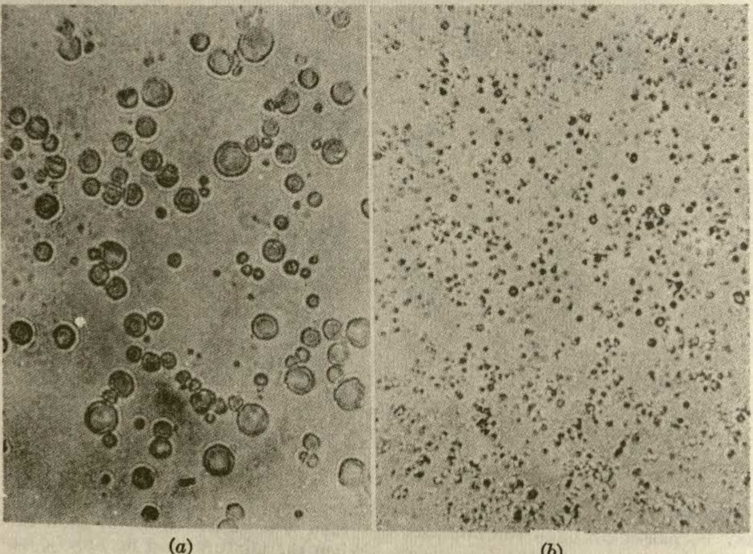

(*a*) (*b*)

FIG. 45. The influence of the homogenizer on the fat globules. Fat globules shown in (*a*) represent the appearance of fat globules in cream. The sample is diluted in order to show more clearly their appearance. In (*b*) are shown fat globules from some of the same cream after being homogenized at 2,000 pounds pressure. Magnified 960 times.

viscosity of milk or cream, which means that the smaller fat globules must overcome a greater resistance if they are to move upward. The increase in viscosity is attributed to the fact that a larger proportion of the proteins of milk will be adsorbed on the surfaces of the greater number of fat globules.

When milk is homogenized, its clotting properties are altered, so that the curd produced when rennet or pepsin is added is said to be softer.

Other effects of homogenization on milk or cream have been reported by various workers. It is known, for instance, that homogenization will bring about an increase in the hydrogen-ion concentration and surface tension of raw milk and cream. In addition it has been observed that homogenized milk or cream may become rancid more quickly than untreated products owing to the hydrolysis of fat by lipolytic enzymes which are adsorbed on the additional surfaces furnished by the more numerous small fat globules. To avoid these changes, the milk or cream must be pasteurized immediately before or after homogenization.

Use of the Homogenizer. The homogenizer is now widely used in the dairy industry in connection with the preparation of market milk and cream, evaporated milk, ice-cream mix, and in the manufacture of cream cheese and certain types of cheese spreads.

When milk or cream has been passed through the homogenizer, the fat globules will not rise readily. Market milk placed in a bottle will show no cream line after homogenization. The fat globules are evenly dispersed throughout the milk and thus when such milk is served in public places there is no necessity for agitating the milk to distribute the cream before serving. Market cream passed through the machine shows no line between the fat and skim-milk layer. It therefore has a more uniform appearance than ordinary cream. Such cream is more viscous and thus appears richer than untreated cream.

In the manufacture of evaporated milk it is important that the fat globules be reduced in size to avoid churning upon agitation. The process of homogenization has been used in this industry for many years.

In the preparation of the ice-cream mix, the entire mixture is passed through the homogenizer immediately after pasteurization. The result is a smoother texture in the finished ice cream than can be obtained otherwise. In addition, the ice-cream mix may be frozen without danger of churning the fat globules in the freezer, as cream which is homogenized at high pressure cannot be churned under normal conditions. A two-stage homogenizer is frequently used in ice-cream manufacture. A relatively high pressure is maintained on the first valve and a relatively low pressure on the second valve. The result of this procedure is a reduction of the viscosity that may occur normally when the ice-cream mixture is homogenized at a relatively high pressure.

Likewise, cream to be used in the making of cream cheese is homogenized to ensure the even distribution of the fat in the finished cheese. In many instances the cream cheese is pasteurized following manufacture and the heated cheese passed through the homogenizer directly into containers in which it is marketed. The finished product is of a very smooth texture.

Reconstituted Milk and Cream. Reconstituted milk or cream can be prepared by use of the homogenizer by mixing butter oil or butter with skim milk. Skim milk may be freshly separated or prepared from dried skim milk and water. Such a practice may be followed by various dairy manufacturing plants during a season of shortage or in sections where the production of milk fails to meet the local demand for dairy products.

EMULSIFICATION

In addition to the machines known as "homogenizers" there are a number of machines used in dairy plants and designed to accomplish somewhat the same purpose. These are known as "emulsors," "emulsers," "creamers," and "emulsifiers." These machines act on the fat globule but do not reduce its size as markedly as do the homogenizers. Neither do these machines influence the viscosity or affect the proteins of milk as noticeably as the homogenizers. In general, there are two types of machines used for the emulsification of milk and cream. One works on a principle similar to that of a steam injector, drawing the milk or cream into a tube from which it is discharged with considerable force against a cone of fine wire mesh. The other type has the outward appearance of a cream separator. By subjecting milk or cream to centrifugal force and releasing it through tightly fitting steel discs or through small openings a reduction in size of the fat globules results. The machines are used, primarily, in small milk plants where it is desired to produce "coffee cream" on which the fat will not readily rise.

PREPARATION OF SOFT-CURD MILK

The demand for soft-curd milk has been increasing since attention was called to the fact that certain samples of milk produce a "soft" curd when coagulated by rennet or pepsin. There seems to be evidence that such milk is more easily digested than milk which produces a "harder" curd under similar conditions. Some cows produce naturally soft-curd milk so that the consumer may be supplied with selected milk from certain cows or even herds that produce such milk. Ordinarily, the softest curd is produced in Holstein milk, followed by Ayrshire, Brown Swiss, Guernsey, and Jersey milk. The milk that is low in solids usually forms a softer curd. The so-called "Hill test" for determining the relative curd tension of milk is used to select soft- from hard-curd milk. If the curd tension is low, it signifies that the milk is soft curd.

It is possible to prepare soft-curd milk by subjecting milk to various treatments. Homogenization has a tendency to reduce the curd tension. The same is true when milk is subjected to sonic vibrations. When milk is heated to high temperatures, the curd tension is lowered. This is one reason why evaporated milk has been used so successfully in infant feeding. A special base-exchange method has been devised for preparing soft-curd milk. The process is quite similar to water softening. Tryptic enzymes have also been employed for the purpose of reducing curd tension. Several other methods have been suggested including the addition of certain salts such as citrates or phosphates. In general, the selection of naturally soft-curd milk, homogenization, sonization, and heat-treatment have proven most practical and least objectionable.

VITAMIN FORTIFICATION OF MILK

The preparation of vitamin D milk has become quite widespread following the accumulation of knowledge concerning the value of this vitamin in the diet and of methods for fortifying milk to furnish more adequate quantities of this antirachitic factor. Milk may be increased in vitamin D content by several methods, but those used most commonly are (*a*) feeding irradiated yeast to cows, (*b*) direct irradiation of milk with ultra-violet light, and (*c*) the addition of vitamin D concentrates to milk.

More recently other vitamins have been added such as vitamin A in the form of carotene, vitamin B-complex through thiamine chloride, riboflavin, nicotinic acid, and calcium pantothenate, and vitamin C as ascorbic acid.

CHAPTER IX

MARKET MILK

The term "market milk" is understood to mean milk in the fluid state, sold to the consumer for direct consumption. In this way, it is differentiated from milk which is destined for use in the manufacture of dairy products, such as cheese, butter, ice cream, condensed, or dry milk. Market milk, in a general way, also includes the cream sold directly to the consumer for household purposes.

The market-milk industry is one of tremendous size considered either from the amount of product concerned, the number of people who work in the industry, or the capital represented. First of all, nearly all of the city and the village population, numbering over 125,000,000 in the United States, are milk consumers. On the average, each person in this country consumes about 40 gallons of milk yearly, or slightly less than one pint a day. Approximately 2,000,000 persons are engaged in caring for the cows that produce the milk and in getting the product to the market. New York City alone uses over 4,000,000 quarts of milk. Placed in tank cars, each holding 50,000 pounds, this would require over 160 cars to haul the milk supply for one day. The milk producers receive for the milk, sold at wholesale for market-milk purposes, the sum of nearly $3,300,000,000 annually, while the cost to the consumers is practically double this figure.

Stages of Development. The market-milk industry has developed coincidentally with the growth of the large urban centers of population. The industry has its foundation in the milk supply furnished almost in the dooryard by the family cow In many instances this situation still exists. With the development of communities, certain families buy their milk from neighbors who keep enough cows to supply local demands. Under these conditions the consumer is in a position to know the methods practiced in producing and handling the milk and the product reaches him promptly, usually within a few hours after milking.

The small city, ordinarily, is supplied with milk produced on specialized dairy farms within a few miles of the city and often delivered by the dairyman directly to the consumer. Under these conditions the consumer usually knows the source of his milk supply and can readily obtain some information concerning the conditions under which the business is conducted. As the city becomes larger, a supply of this type becomes inadequate, and the conditions are such that it is no longer profitable to operate dairies near the city.

The next stage is shipment by train or by truck. Farmers some distance from the city, learning of the good market for milk afforded by the city, arrange with the railroads for special transportation in the form of milk trains scheduled at suitable hours. This makes possible the production of milk where the land is relatively cheap, and where the feed for the animals is produced, for the cities many miles away. The individual producer no longer can deliver milk to the consumer. An intermediary organization, therefore, takes over the distributing function, buying milk from the producer, processing it in suitable plants, and distributing it to the customers.

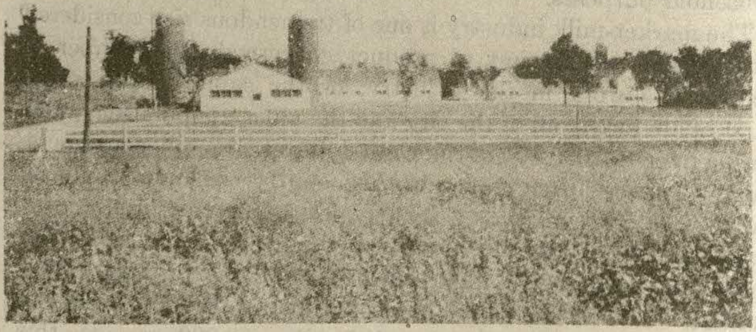


FIG. 46. A modern dairy barn. It will be noted that the buildings and premises are well cared for and that everything appears clean and orderly. Plenty of light and ventilation are provided.

Complexity of the Problem. In every state, the practices described may be observed, namely, the family cow, the local dairyman selling directly to the consumer, and about every large city, the complicated organizations necessary to supply the great center of population. The complexity of the problem is evident. New York, for example, receives milk from thousands of farms representing at least ten states and two provinces of Canada. Regular daily shipments are made for a distance of nearly 500 miles. Sweet cream is shipped by carloads from Ohio, Wisconsin, Minnesota, and other Middle Western states, to supply the cities of the eastern seaboard. Milk is shipped in tank cars from Wisconsin to Florida.

The time that necessarily must elapse from the time the milk is produced until it reaches the consumer requires the use of the best methods and equipment modern science and engineering have been able to devise. Furthermore, it is evident that business enterprises with large financial resources and competent management must shoulder the responsibility of organizing the collection of the milk in the country, the transportation to the city, the processing in the city, and, finally, the sale and distribution to millions of consumers.

The Necessity for Public Supervision. It is clear that when the source of supply is removed to a point many miles distant, the milk cannot reach the consumer so promptly as when it is purchased from a neighbor. Milk is a very perishable food product, outstanding in importance as a food, but dangerous if not in proper condition. During shipment, or when the milk reaches the city distributing plant, it is placed in large containers each of which contains the milk from scores of farms. As a result of these conditions, which are necessary in supplying a large city with milk, the city consumer seldom if ever sees the farms where the milk which he uses is produced. In fact, the typical consumer in the large city never even visits the city distributing plant from which his milk is purchased, and has no information whatever as to the source of the product he uses. The consumer no longer has any means of judging the conditions under which his milk has been produced. He is not qualified to judge concerning the freedom of the product from adulteration or contamination. Clearly some governmental agency must take over this function.

PRODUCTION OF MARKET MILK

The starting point in the market-milk industry is the farm. The farmer who undertakes the production of market milk is confronted with many serious problems. First of all, he must be able to obtain a fair return for the use of his capital and labor. The successful accomplishment of this end involves the difficult problems of maintaining a healthy herd, breeding and raising, or purchasing, cows with sufficient milk-producing capacity to make possible economical milk production. The entire farm must be properly organized to make possible a satisfactory income without too great an expense for labor. The farmer must understand the feeding and the care of dairy cows and how to supervise labor. Feed must be grown so far as is practical and economical, and the remainder purchased to the best advantage. Finally, his product must be marketed to the best advantage. These requirements concern the economics of production. The milk producer is confronted with still other exceedingly important questions; such as that of maintaining conditions on the farm which will make possible a safe, clean product acceptable to the city consumer and the control official. A consideration of the economic factors is beyond the scope of this discussion. Attention will, however, be directed toward those problems of health, cleanliness, and keeping quality of the product, which must be taken into account to insure a wholesome and a safe milk supply.

Clean, Healthy Cows. Inasmuch as certain diseases may be transmitted through the milk from a cow, it is absolutely essential that all cows that are producing milk for the market trade should be free from any infectious or contagious disease. A healthy cow is a prime requisite for safe milk. All milk-producing cows should be free from diseases such as tuberculosis, brucellosis, mastitis or garget, actinomycosis or lumpy jaw, etc. Regular tuberculin tests should be made and all infected animals removed from the herd. Blood tests for brucellosis will make it possible to eliminate cows suffering from this disease. Whenever the udder of a cow is inflamed or swollen, as it is when the animal is affected with garget or mastitis, and the milk is abnormal and made up largely of stringy, watery substances, such milk should be discarded, the animal isolated from the rest of the herd, and a veterinarian consulted. Conditions such as actinomycosis (lumpy jaw), running sores, etc., are sufficient reasons for rejecting the milk for human consumption. In other words, whenever a cow is suffering from some disease or infection there is a possibility that disease-producing bacteria may find their way into milk and be responsible for serious infections in children or adults who consume such milk.

Much of the dirt which gains access to milk comes from the body of the cow, particularly from the flanks and udder. When the cow is kept clean, the purity of the milk is enhanced as well as its keeping quality. At the time of milking the cows should be especially clean. It is a very good practice to keep the udder and rear quarters clipped and to wipe them off with a damp cloth just before milking. The habitat of the cow is such that she naturally picks up considerable dirt on her shaggy coat and it becomes absolutely necessary to pay some attention to the cleanliness of her posterior regions if clean, wholesome milk is to be produced.

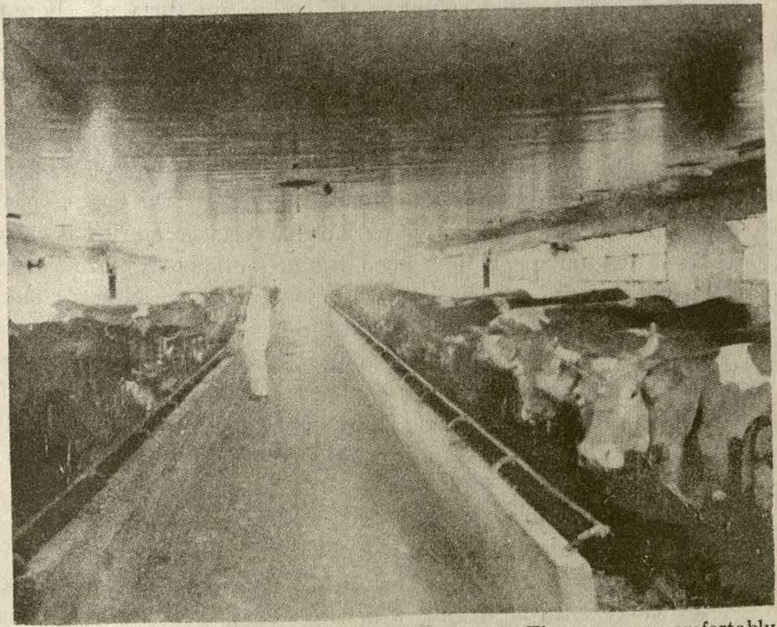


FIG. 47. Interior view of a modern dairy barn. The cows are comfortably chained in a new type of stanchion. There is ample light and ventilation. (*Courtesy of Sanitary Farm Dairies, Inc.*)

Proper Construction of Barns. The cleanliness of stables, particularly of stalls, floors, and gutters, is of vital importance from the standpoint of the cleanliness of the cow. The construction of the barn has a great deal to do with this. Stalls should be of proper length so that the droppings of the cow fall into gutters provided to catch them. Floors and gutters should be made of impervious material such as concrete and be sloped sufficiently well so that all liquid material may drain away promptly. Walls and ceilings should be tight so that they may be kept clean and not be resting places for dust and dirt. If the floor of the stable is kept clean, and fresh, clean bedding is provided, the animals are not so apt to become dirty as where there are accumulations of manure and filth to soil continuously the flanks and udder. Clean, healthy cows are an absolute requirement.

Small-mouthed Pail. One of the most satisfactory methods for keeping down the bacterial and dirt content of milk is the so-called small-mouthed or hooded pail. By the use of this type of milk pail a considerable part of bacteria-laden dirt is excluded from the milk. It has been found sufficiently satisfactory to justify special emphasis. Of course, if a milking machine is employed, that serves the same purpose unless it is carelessly handled in moving from cow to cow. Even in this case the small-mouthed pail should be used for strippings. By means of the hood over the pail, a good share of the dirt which might fall into the milk pail from the body of the cow is diverted. In this way the quality of the milk is certain to be enhanced.

Clean, Healthy People. Any one intimately connected with the production or handling of milk should be in good health and be clean in his habits. Certain of the serious epidemic diseases are carried through milk which has been infected by persons in contact with the milk at some point at the dairy farm or before it reaches the consumer. The personal factor is of tremendous importance in the production of a clean milk. If the milker is slovenly in his habits, it will usually follow that he is careless in his methods about the dairy, neglecting the cleaning of cows or the stable, the washing and sanitizing of utensils, and other necessary procedures. On the other hand, where the dairyman is careful about his personal habits, dress, etc., he usually will be attentive to all details of sanitation. The personnel employed on dairy farms and elsewhere in the milk business should be free from contagious or infectious diseases and be neat in person and in their care of the animals and details of dairy hygiene.

Clean and Sterilized Utensils. Under ordinary farm conditions the utensils are to be considered as the greatest single source of bacteria and often contribute large numbers of organisms to an otherwise high-quality milk. Clean, sanitized, and *dry* utensils are absolute necessities in the production of milk with a low bacterial content and high keeping quality. Milk is brought into contact with a great variety of utensils from the time it leaves the cow until it is placed before the consumer. As was previously pointed out, utensils often are serious sources of contamination, and have a great influence upon the keeping quality of the milk. The utensils not only must appear clean but be clean bacteriologically. This means that they must be rinsed, washed, and sanitized as soon as possible after they have been used. Metal utensils such as pails, cans, separator parts, etc., should be rinsed with cold or lukewarm water after each milking; that is, morning and night. This removes much of the milk. After this is done they should be washed and scrubbed with a brush, using plenty of clean, warm water to which some detergent or washing powder has been added. This is necessary in order to rid the utensils of the film of fat. Then they should be rinsed with plenty of warm or hot water before being sanitized. They may be sanitized ("sterilized") by means of hot water, steam, or chemicals such as the chlorine solutions of one kind or another. The hot water or steam is to be preferred if there is an ample supply of either. The point to bear in mind, however, is that the water must be hot enough and used in sufficient quantities so that it may "sterilize" and make the metal so hot that it is uncomfortable to touch with the bare hands. If steam is used it must be applied sufficiently long to do likewise. When this is done the utensils will dry quickly and, as pointed out elsewhere, this is a very important part of the effectiveness of "sterilization" and prevention of further growth of microörganisms. Where hot water and steam are not available one may resort to the use of some of the hypochlorite or chloramine solutions. These are quite effective if used when they have the proper amount of available chlorine (not less than 50 parts per million) and when the utensils are cleaned thoroughly.

Strainer cloths, if used, should be washed, boiled, and dried after each milking period or, better than that, a new filter disc should be used at each milking.

The Milking Machine and Separator. The milking machine has found its way into dairying more extensively each year. It is a labor saver and the majority of milking machines on the market are reasonably satisfactory mechanically. From the standpoint of clean milk production, there is no reason why a high quality of milk cannot be produced where milking machines are used, provided the parts of the milker in contact with milk are kept scrupulously clean. Where milking machines are employed especial care must be exercised to maintain them in a good sanitary condition. They should be rinsed, washed, and "sterilized" twice a day. The latter may be accomplished most satisfactorily by means of hot water over 180°F. (82.2°C.). The rubber tubes and teat cups may be stored between milkings on a so-called "solution rack" where they may be exposed to a chlorine or lye solution, which will inhibit bacterial growth.

The separator is a piece of equipment which is often neglected. The parts of the separator that come into contact with the milk, cream, or skim milk should be washed, "sterilized," and dried each time after they are used; otherwise, there is an accumulation of remnants of milk and slime in the bowl which contribute tremendous numbers of microörganisms to milk passing through such a neglected separator.

Prompt, Efficient Cooling. Inasmuch as milk produced even under the very best conditions contains some bacteria, it must be cooled as soon as possible in order to check the growth of the organisms present and maintain the keeping quality of the milk. As soon as the milking is completed the milk should be cooled thoroughly. This may be accomplished in a number of different ways. The milk may be passed over a special cooler after milking each cow or as a whole when the herd is all milked. Cans may be placed in a tank of cold water and each pail of milk emptied into the can immediately. Otherwise, the filled cans may be set in a tank of cold or iced water and cooled. Cooling is facilitated and accelerated by frequent stirring of the milk or water. The best cooling medium is water or brine. These may be utilized through the agency of the coolers mentioned previously or in a satisfactory cooling tank. The thing to bear in mind is that the milk should be cooled just as quickly as possible, while the means will depend upon the facilities available or the preference of the dairyman. Cold air is a very poor medium for cooling. Even when the temperature is below zero, milk will be cooled much more slowly in such air than in water at 50°F. (10°C.), as is illustrated in Table XIII. All milk should be cooled as quickly as possible after the milking and the temperature reduced to below 50°F. (10°C.) if good keeping quality is to be assured.

TABLE XIII. COMPARISON OF VARIOUS METHODS FOR COOLING MILK

Cooling medium	Stirring	Temperature of cooling medium, degrees Fahrenheit	Temperature of milk			Loss of temperature	
			Original, degrees Fahrenheit	After 1 hour, degrees Fahrenheit	After 2 hours, degrees Fahrenheit	1 hour, degrees Fahrenheit	2 hours, degrees Fahrenheit
Air......	No	+8 to −4	90	80.0	69.0	10.0	21.0
Air......	No	36 to 38	89	82.0	75.0	7.0	14.0
Air......	Yes	36 to 38	90	82.2	76.0	7.8	14.0
Water....	No	45 to 49	90	58.0	50.0	32.0	40.0
Water....	Yes	45 to 49	88	52.0	46.0	36.0	42.0
Ice water	No	40 to 45	88	56.0	46.0	32.0	42.0

Prompt Delivery. Milk which is intended for market-milk purposes should not be allowed to accumulate, even if kept cool. It should be delivered to the consumers or distributing plants daily. Fluid milk should be fresh as well as clean, cool, and safe when delivered to the ultimate consumer.

Certified Milk. There are many refinements which can be made in the methods and the equipment employed in the production of milk for the market trade. For example, there has grown up a grade of milk known as "certified" which is produced under exceptionally careful conditions, with special equipment, additional precautions, and control of every conceivable factor influencing the quality of milk.

About 60 years ago, some physicians in New Jersey became interested in the production of a superior quality of milk. They made a study of sanitary methods of milk production and selected a dairyman who agreed to comply with the regulations set down by this group of doctors. This medical group established what is now known as a "Medical Milk Commission" to supervise the production of the milk on this farm. The first "certified milk" was produced under its jurisdiction in 1894 in Essex County, New Jersey. The term "certified milk" has been registered in the U.S. Patent Office and is protected from misuse under that arrangement. Since that time medical milk commissions have been set up all over the country. They have adopted uniform standards for the production and distribution of certified milk. The regulations are very much in detail and very strict. The supervision of the certified dairies, in recent years, sometimes has been delegated to state departments of health. The certification of equipment and methods has continued to be strict, and certified milk stands out as milk which is produced under the most exacting conditions. It represents the highest quality of raw milk that is obtainable. The originators of the idea are to be commended for their careful study and diligent efforts. They established a precedent and a standard for sanitary milk production which have influenced, for the better, all market milk. The conditions under which certified milk is produced are nearly ideal and serve as a goal toward which all conscientious dairymen should be guided.

Provisions are now made for pasteurized certified milk. This adds one more factor of safety to an otherwise ideally safeguarded milk supply.

The dairy industry cannot be too careful in the production of milk which is to be used by such a large number of people who are so far away from the source of supply.

Transportation of Milk. The channels of transportation through which milk passes from the time it is produced on the farm until it reaches the door of the consumer are dependent upon the local situation. Where the producer delivers directly to the consumer, the transportation merely involves a delivery by wagon or truck from the farm to the town. When the producer sells to a distributor some distance away there may be involved hauling by truck or shipment by rail.

The farmer may, himself, haul the milk to the milk-receiving station or to the city distributor's plant, if close at hand. Often arrangements are made for trucks operated by the purchasing agency to pick up the milk at the individual farms and transport it to the shipping station or distributing plant. In this case, a charge for hauling is usually made and based upon the distance. A considerable part of the milk going to the great urban centers is collected first at country receiving stations located at frequent points along the railroad. In these country receiving stations

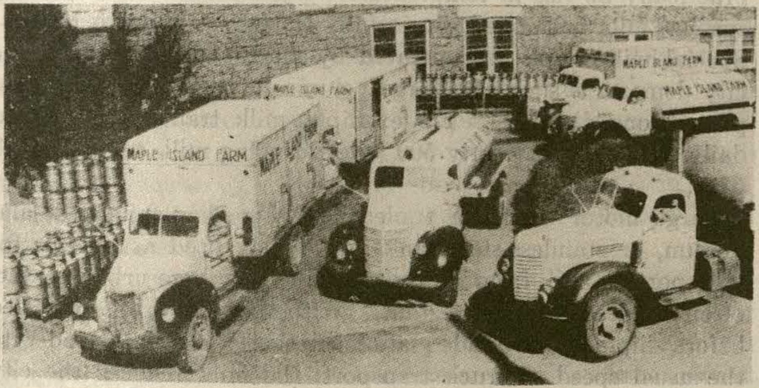


FIG. 48. Various types of motor vehicles, including tank trucks, used for transporting milk. (*Courtesy of Maple Island Farm, Inc.*)

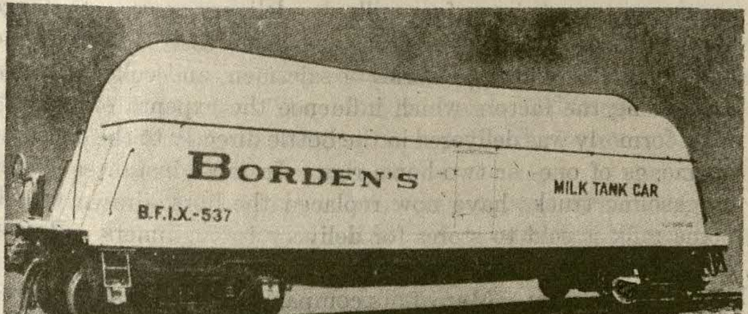


FIG. 49. A modern, streamline milk tank car used for the transportation of milk over long distances to the larger cities. There are two 12,000-quart, cork-insulated, glass-lined tanks set in either end of the car. The outside shell is steel with a protective coating of aluminum metal fused to the steel surface. (*Courtesy of Borden's Farm Products Company.*)

the milk may be pasteurized, or merely thoroughly cooled before shipment. Until recent years, shipment was made in ordinary 8- or 10-gallon cans. Usually, blocks of ice were placed on top of the cans to help maintain a low temperature. Recent improvements involve the use of glass-lined, aluminum, or stainless-steel tanks mounted on gondola cars or enclosed by the superstructure of an ordinary freight car. These tanks are usually insulated in such a way that it is possible to ship milk long distances with practically no rise in temperature. By the use of this modern system, milk is shipped successfully from Wisconsin to Florida. Special milk trains are operated by many railroads where the city demand is such that large volumes of milk must be transported long distances. For example, milk trains are operated daily a distance of nearly 500 miles bringing milk to New York City.

Large motor trucks or trailers carrying glass-enameled, aluminum, or stainless-steel tanks are widely used at present for transporting milk from rural districts to the large urban centers often hundreds of miles distant. With the milk properly cooled before shipment, with adequate insulation of the tank, and with the usual speed of truck transport, the milk reaches the city plants in excellent condition.

Delivery of Milk. One of the major items in the price which consumers must pay for milk is delivery cost. Distances between customers, cost of delivery outfits, cost of maintenance and operation of them, salaries of salesmen, and collection costs are among the factors which influence the expense of delivery. Milk formerly was delivered in the bottle directly to the consumer by means of one- or two-horse rigs. In most instances electric or gasoline trucks have now replaced the horse-drawn vehicle. Some milk is sold to stores for delivery to customers. Restaurants, hotels, etc., purchase some milk by the can and so reduce the handling costs. Many milk companies also handle such products as buttermilk or other fermented milk beverages, cottage cheese, butter, etc. This tends to increase the burden of delivery but makes it possible for the dealer to utilize his surplus products to good advantage. With all the details of overhead and operating expense involved in the delivery, it is not surprising that it constitutes a considerable part of the cost of a quart of milk.

Purchase of Milk. Milk may be purchased by a distributor in a variety of ways, such as:

1. By measure—that is, by quart, gallon, or can.
2. By total weight, estimated or actual.
3. By either (1) or (2), with minimum standards of milk fat

and a premium for additional milk fat and premium for high quality or deductions for poor quality of milk.

4. By weight and test, paying upon the basis of milk fat delivered.

5. By weight and test, with a basic price per 100 pounds of skim milk plus a straight price per pound of milk fat.

The majority of milk, at present, is purchased upon the basis of weight with a minimum standard for milk fat, and a premium for additional milk fat above the standard, and in many sections with deductions made for a poor quality of milk. The method varies in different localities but there is a tendency toward purchase by weight and milk-fat standards in most dairy sections because of the competition with creameries and cheese factories.

In some cases, cooperative organizations collect the milk produced by the members and sell it at wholesale to distributors. Again, cooperative organizations may undertake the distribution of milk. The fact that a cooperative organization is concerned does not affect the methods involved in supplying a city with milk. It does affect, however, the nature of the business organization concerned.

The Milk Plant. It is beyond the scope of this text to discuss in detail the construction, equipment, arrangement, and operation of milk plants. They vary so much in different sections and the methods are changing so rapidly that only a meager picture of them can be drawn.

The modern milk plant is housed in a permanent, well-constructed building that is durable and constructed to facilitate the sanitary and prompt handling of milk. It may be of modest proportions or represent large investments. A typical plant of the latter type is represented in the accompanying figure.

Usually, the plants are provided with a room where the milk is received and weighed. Here the cans may be washed and prepared for return to the farmer. The milk ordinarily will be conducted or pumped into storage tanks from which it will pass through filters or clarifiers before it is pasteurized.

A separate room usually is provided for pasteurization. The heating of the milk may be accomplished in a variety of ways, by means of surface, drum, tubular, or plate heaters with hot water or steam as a heating medium, in special electrical devices

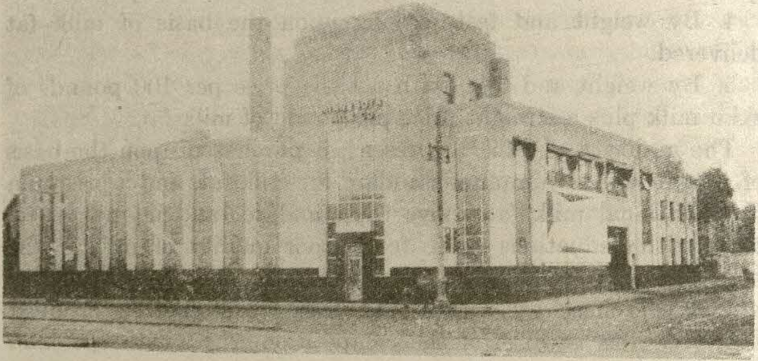


FIG. 50. A modern market-milk plant. (*Courtesy of Minnesota Milk Company.*)

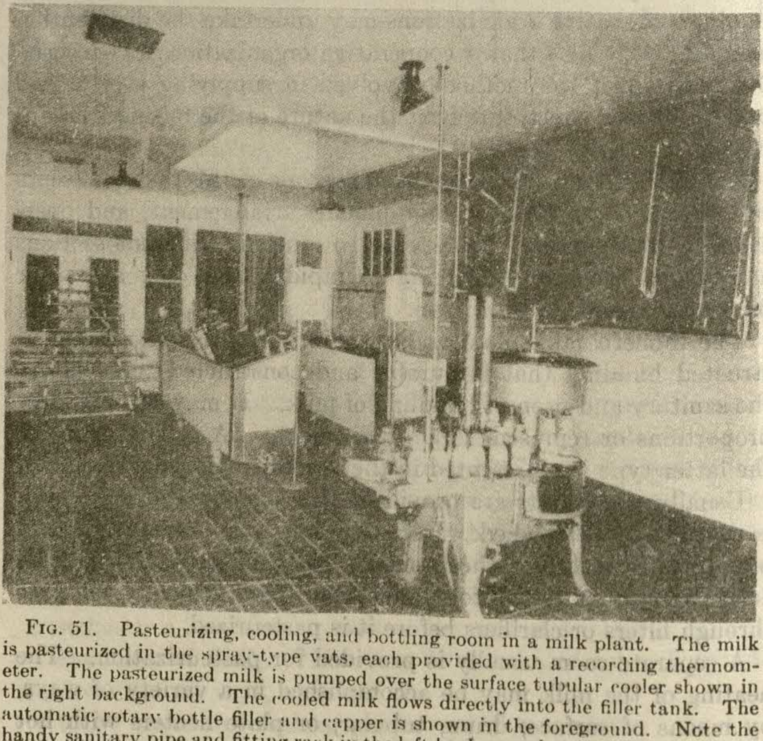


FIG. 51. Pasteurizing, cooling, and bottling room in a milk plant. The milk is pasteurized in the spray-type vats, each provided with a recording thermometer. The pasteurized milk is pumped over the surface tubular cooler shown in the right background. The cooled milk flows directly into the filler tank. The automatic rotary bottle filler and capper is shown in the foreground. Note the handy sanitary pipe and fitting rack in the left background. (*Courtesy of Cherry-Burrell Corporation and Winona Milk Company.*)

or directly in large vats or pasteurizing tanks. After heating, the milk is held for the required period of time and then cooled promptly, either over surface or plate coolers or through internal-tubular coolers. From the coolers the milk will pass directly or indirectly to bottle fillers. Here the milk will be delivered into bottles, which are capped by machinery or in single-service, paper containers of various types. From the bottler the milk passes to a refrigerator where it is stored until delivered.

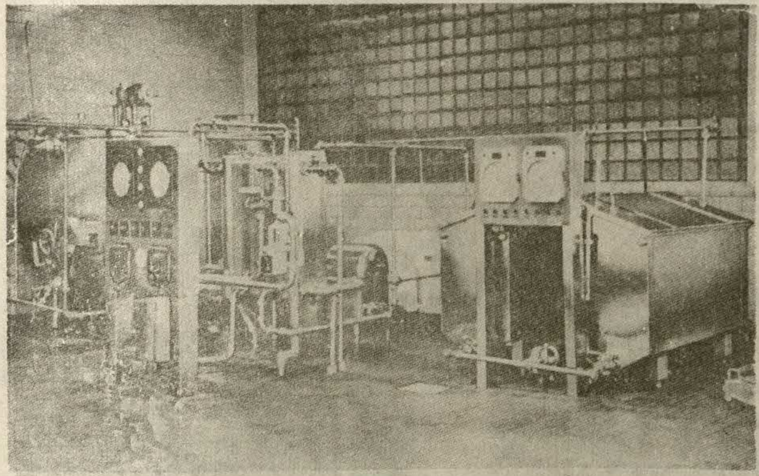


FIG. 52. Pasteurizing equipment in milk plant. The milk, before pasteurization, is held in the stainless-steel storage tank at the left. It is then pasteurized in the high-temperature, short-time plate pasteurizer in the center. The pasteurized and cooled milk is then held in the spray-type vats at the right, which serve as supply tanks for the bottler. Note the control panel in left foreground, with recording thermometers, etc., as well as the recorders in front of the vats on the right. (*Courtesy of Cherry-Burrell Corporation and Sanitary Farm Dairies Inc.*)

In most plants there will be provided a special room for washing bottles returned from the consumer. A place must be provided for offices, machinery, storage of supplies, etc. All machinery must be arranged carefully if economies of operation are to be possible. Each milk plant will have a different arrangement of rooms and equipment. There will be differences between plants in the size of installations and their type. In general, they will have equipment for weighing and receiving milk, washing cans, pumps and piping for transferring milk from one part of the plant to another, storage tanks, filters or clarifiers, heaters, pasteurizers and coolers, bottle fillers and cappers, bottle-washing equipment, and provisions for refrigeration. They will all require heating plants, storage rooms, and some sort of office. Additional equipment, such as horses, wagons, trucks, and barns or garages, must be provided.

Some plants are very modest in their investments while others represent the expenditure of thousands or even millions of dollars. Interior views of representative plants will give an idea as to the type and variety of equipment which is necessary for the modern milk plant.

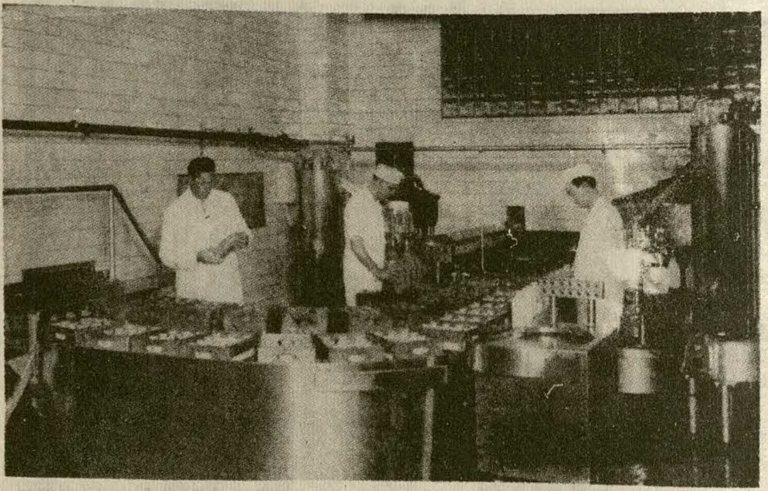


FIG. 53. Bottling room in a milk plant. The clean and sterilized milk bottles are discharged on a conveyer directly from the bottle washer located beyond the partition shown in the background. The bottles pass directly to the automatic rotary bottle filler and capper. The filler operates under a vacuum. The filled bottles are inspected by the attendant and placed in cases, which in turn are conveyed into the refrigerator. (*Courtesy of Sanitary Farm Dairies, Inc.*)

Problems of the Milk Distributor. The operators of milk plants are confronted with many perplexing problems. They must be able to obtain a high-grade raw product, handle it expeditiously and economically. When pasteurization is practiced, due care must be exercised in the process so that the normal characteristics of milk may not be altered appreciably. This applies particularly to the matter of flavor and of creaming ability. As long as the housewife measures the quality of milk by the depth of the cream layer at the top of the milk bottle, it will be necessary for the plant operator to take all precautions to preserve the cream line as much as possible. The operation of all equipment, together with the selection of the most satisfactory installation, will have a great deal to do with the success which a milk dealer may attain in supplying the consumer with the type of milk most desired.

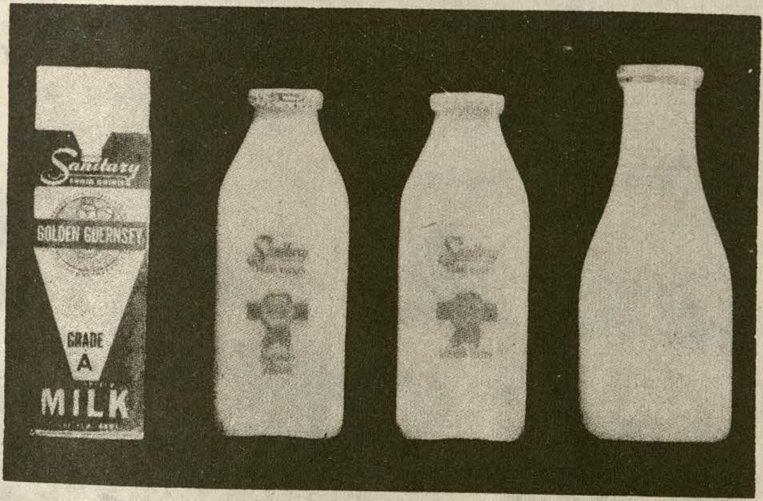


FIG. 54. Containers in which market milk is delivered to the consumer. The package at the left is one type of paper single-service container being used on many markets. The center bottles have fused-color lettering and design to identify the distributor and have the pouring lip adequately protected by a cover cap, required by some health departments. The bottle on the right has the conventional flat disc cap. (*Courtesy of Sanitary Farm Dairies, Inc.*)

HEALTH CONTROL OF MILK SUPPLIES

The milk supply often is rated as second only to the water supply, as a factor concerned with the health of a city. As pointed out, previously, it is impossible for the city milk consumer to have any knowledge concerning the conditions under which his milk supply is produced. It is also evident that under any conditions few would be able to determine for themselves the wholesomeness of the milk. With the growth of the cities and the increased knowledge concerning the importance of the milk supply as a health factor have come well-organized departments in city governments having as their duty the careful supervision of the milk supply.

The first attempts toward supervision of the milk supply date back about 70 years in the United States. The first efforts were directed toward the elimination of such frauds as watering milk or selling as whole milk that from which a portion of the cream had been removed. Such adulterations were common in those times. A little later, the use of chemical preservatives became common as means of improving the keeping qualities of milk. This practice was also under the ban of law, and food-control officials were given the responsibility of eliminating the practice. The practice of skimming and watering milk for sale and the use of preservatives have been eliminated almost entirely as the result of these efforts. The elimination of these practices is now accepted as a matter of course and the attention of public officials is directed more toward the cleanliness, wholesomeness, and safety of milk. There are many methods in use for exercising control of the milk supply but all have the same objective —that of protecting the public and ensuring for it a safe and satisfactory milk supply.

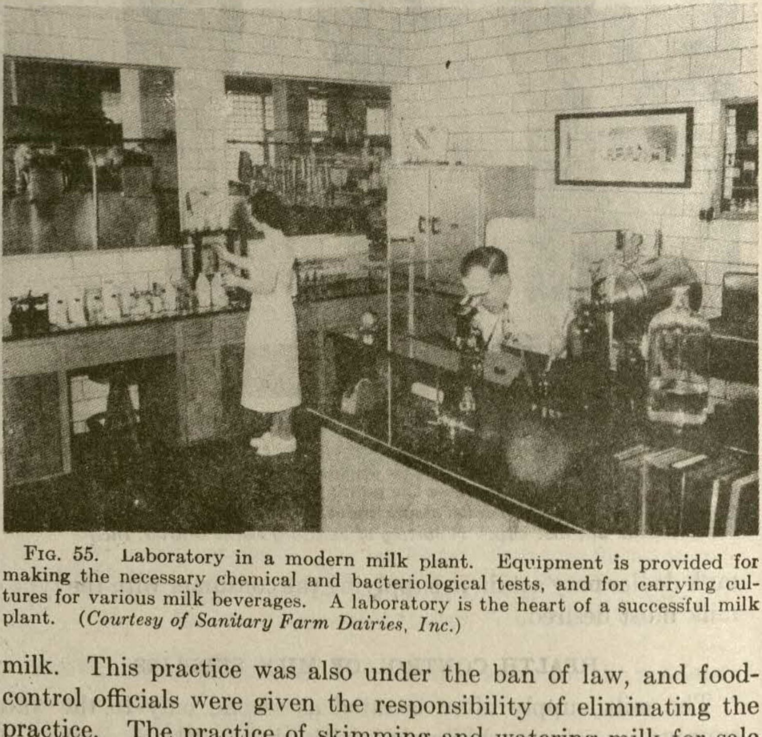


FIG. 55. Laboratory in a modern milk plant. Equipment is provided for making the necessary chemical and bacteriological tests, and for carrying cultures for various milk beverages. A laboratory is the heart of a successful milk plant. (*Courtesy of Sanitary Farm Dairies, Inc.*)

Federal laws regarding foods apply only to interstate shipments and are, therefore, not depended upon to regulate local milk supplies. State laws, as a rule, set forth requirements which must be met in producing, handling, and distributing milk as well as other food products. As a rule, both federal and state laws consist mainly of definitions and regulations regarding the fat and the total solids content of milk, prohibiting the use of preservatives, and, in general terms, requiring production and distribution under good sanitary conditions. Adequate supervision of the milk supply is usually the result of city ordinances which add details to regulations and laws of state and federal origin and provide for the personnel necessary to carry them into effect.

Control Measures. The usual plan is to require every milk distributor to have a permit or license to sell his products. To obtain this permit the product sold and the conditions under which it is produced and handled must conform to the requirements of the regulations. In some cities emphasis is placed upon the sanitary conditions of the premises used in producing and handling milk. In others the actual condition of the milk as offered for sale receives the greater attention. As a rule, the control is more or less of a combination of the two.

Supervision in the Small City. In a small city having a typical ordinance, evidence that all cows contributing to the milk supply had passed the tuberculin test and others would be required at intervals. The dairy barns and the premises would be inspected at intervals by an inspector working under supervision of the Department of Health. In making this inspection use would be made of a dairy-farm score card. A copy of the score card as filled out is left with the farm owner. This score card covers important items of construction, equipment, and methods in the dairy barn and serves to make possible a permanent record of the conditions existing, also to point out definitely to the farm manager the places where improvement should be made. If the milk supply for the city goes through a milk plant, these premises and the methods practiced also are subject to inspection at regular intervals.

In addition to the sanitary inspection of premises, samples of the milk would be taken at frequent intervals from delivery wagons. The fat and total solids content of these samples will be determined and, in addition, many health departments also make bacterial counts of the milk. The sediment test may also be employed. If conditions are found which do not conform to the regulations, the license of the milk seller may be canceled. There is little tendency for arbitrary action on the part of control officials, and producers or distributors whose product is below standard are usually given plenty of opportunity to make the necessary improvements.

Supervision in the Larger Cities. In the large cities, the health control is conducted along similar lines but requires some modification. It is evident that, with 45,000 farms supplying New York City, it would be impossible to exercise a close supervision over the sanitary conditions under which the milk is produced. The quality of the milk must be determined largely from an examination of the product itself as offered for sale, and by a supervision of the conditions under which the milk is handled. Occasional inspection is generally made of the farms, more frequent examinations are made of the sanitary conditions and practices in the country receiving stations, and a rather close supervision exercised over the quality of the milk, as sold in the city, including the practices and methods followed in the city pasteurizing plants. A health examination is sometimes made of the employees of the city plants.

Pasteurization as a Health-control Measure. There are certain cities and states in the United States which require that all market milk be pasteurized. The majority of cities however, permit the sale either of raw or of pasteurized milk. In most of the larger cities (that is, those with populations over 100,000) it will be found that 95 per cent or more of the market milk is pasteurized. Because of the difficulty of inspecting and regulating large numbers of widely scattered dairies supplying a large city with milk, it necessarily follows that most of the milk under these conditions must be pasteurized. Pasteurization has the advantage of reducing the transmission of disease-producing bacteria, diminishing infant mortality, and improving the keeping quality of the milk. Large volumes of milk may be brought to central plants for pasteurization and handling where rigid inspection and control are possible. In this way, the public is protected more adequately. Pasteurization is not intended to cover up faulty methods of production or handling. Rather, it is primarily a health measure to make good milk safer for human consumption and makes possible a wholesome milk supply, especially for large cities.

Most cities sanction the sale of raw milk. Certain of these restrict this to certified milk. Others permit other grades of raw milk to be sold, but the tendency is to limit the sale of raw milk to those dairies that are well equipped and rigidly inspected, and to require the tuberculin testing, blood testing for brucellosis, and frequent physical examination of cows and medical examination of handlers, besides setting up exacting standards for the bacterial content of the milk.

Reasons for Pasteurization. It must be granted that it is desirable to have the milk supply made up of milk as nearly unaltered in its natural characteristics as it is possible to obtain. This would mean fresh, raw milk as it is drawn from healthy cows, by healthy people and under the very best sanitary conditions, and delivered promptly to the consumer without contamination or alteration due to chemical or microbiological agencies. This situation requires constant attention, careful supervision, and inspection. Conditions so nearly ideal are difficult to attain, and where large cities require such vast quantities of milk that they must go long distances and to many dairies for their milk supply, pasteurization is a practical necessity in order to safeguard the health and well-being of the average consumer. Economic factors also play a part in this situation to such an extent that it is not at all difficult to understand why pasteurization has such an important place in the modern market-milk industry.

Grades of Milk. Market milk often is designated by grades or classes. These vary widely, depending upon the local requirements or demands of the trade.

In a general way, there are two classes of market milk, raw and pasteurized. The raw milk is that which is delivered in its natural state after it leaves the cow and without any treatment other than cooling. Pasteurized milk is milk that has been subjected to temperatures sufficient to destroy all disease-producing types of bacteria that may be present in the raw milk. (Pasteurization is discussed elsewhere in this text.)

Under raw milk would be found the milk known as "certified milk" as well as ordinary raw milk. This latter may be designated in grades such as "Grade A Raw" or "Grade B Raw," or "Inspected Milk," etc. The pasteurized milk ordinarily comes in the one grade, but in certain cities is subdivided into such as "Pasteurized Certified," "Grade A Pasteurized," "Grade B Pasteurized," etc.

The grades are based upon the conditions under which the milk has been produced and handled, as well as upon the quality of the milk from the standpoint of purity, bacterial count, cleanliness, etc. Such grades usually are set up by local regulations.

More recently special classes or types of milk have been introduced on the market. For instance, skim milk, high fat, special Jersey or Guernsey, vitamin D, soft curd, concentrated, and homogenized milks have all found a place in the modern milk market. They present special problems for the industry and the control officials.

In the hands of competent and energetic public officials the milk supply of a community may be safeguarded satisfactorily. Where officials are lax or ignorant, the public is not assured that its milk supply is above suspicion. The problem in controlling the milk supply of large cities is exceedingly great, because the centers of production are widely scattered and adequate inspection is costly and difficult to accomplish.

CHAPTER X

THE MANUFACTURE OF DAIRY PRODUCTS

BUTTER

The use of butter appears to be as old as recorded history. Hindoo writings, dating back to at least 2000 B.C., indicate that butter was used extensively, at that time, both as a food and in connection with religious ceremonies. The oldest parts of the Bible contain frequent references to milk, butter, and cheese. There is, however, some question regarding the use of the term, "butter," in the translation from the original. It is probable that the product, to which reference was made, would hardly pass as butter, according to present-day standards. Butter was used by both the Greeks and the Romans, but apparently more extensively as an ointment for medicinal purposes than as a food. The extensive use of butter as a part of the human diet developed in northern Europe where climatic conditions were more favorable for the preparation of this product. By the twelfth century butter was an important export from the Scandinavian countries.

Early History in the United States. During the colonial period, and in fact until past the middle of the nineteenth century, the making of butter in the United States was exclusively a farm industry. It was in the hands of the women of the household and the methods and utensils were crude. During the winter season scarcely any butter was on the market, while in the summer the supply was so abundant that the price was exceedingly low. The factory manufacture of cheese had begun in 1851 and, following this lead, in 1861, Slaughter built a factory in Orange County, N.Y., to use the milk of 365 cows. From this he made both cheese and butter, the cheese largely from skimmed milk. The credit for the first exclusive butter factory or creamery, as such establishments are now termed, is usually given to Stewart who, in 1871, built such a factory at Manchester, Iowa. In these first factories the whole milk was received at the creamery and placed in large shallow vats to allow the cream to rise. It was, in fact, the shallow-pan system of separation on a large scale. Later, the deep-setting plan was followed, the whole milk still being delivered to the creamery. About 1875, the plan known as the "gathered-cream system" came into use. The only change from the first was that the skimming was done on the farm and the cream taken to the creamery, or commonly gathered by special haulers who operated regular routes.

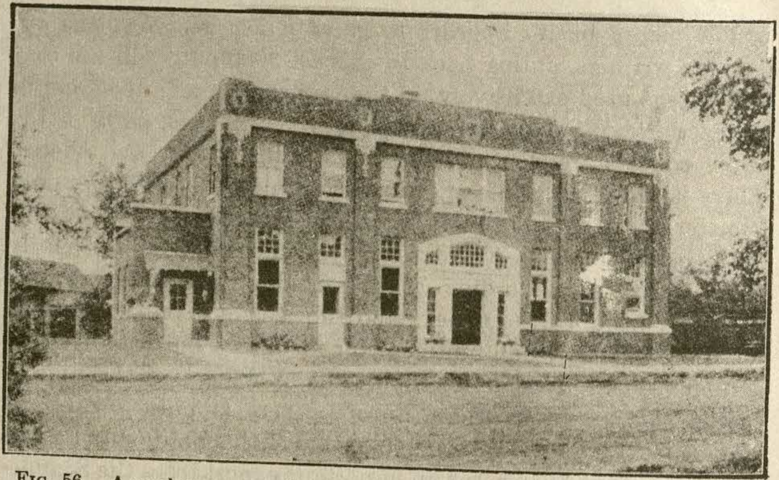


FIG. 56. A modern cooperative creamery representative of the type found in Minnesota. Such a creamery is equipped to manufacture 400,000 to 600,000 pounds of butter yearly. Many creameries in America are much larger and equipped to manufacture several million pounds of butter yearly.

The Effect of the Cream Separator. Beginning in 1879, the centrifugal separator was introduced and this resulted in a rapid change in the plan of creamery operation. The early cream separators were all power sizes and, as a result, the creameries soon were equipped to separate milk by these more efficient methods. The practice of gathering hand-skimmed cream from farms was within a few years replaced by that of bringing the whole milk to the creamery, the farmer usually receiving his share of the skimmed milk to be taken home for feeding purposes. Not only was the loss of milk fat greatly reduced, but a decided improvement in the quality of butter was possible.

In 1890, hand-power farm-size cream separators came on the market. Another change in the plan of creamery operation resulted. By means of the farm separator, the cream producer could secure the same efficiency of separation as at the factory and, at the same time, secure the skim milk in much better condition for feeding purposes. The hauling expense likewise was reduced because of the smaller quantities to be handled and the less frequent deliveries. Although a few creameries continued the plan of receiving whole milk and operating a power separator, it may be said, fairly, that the butter-making industry in the United States, after about 1910, was based upon farm-separated cream. The creamery operator, however, found more difficulties in maintaining the standard of his product. On the whole, the farm-separator system undoubtedly resulted in a lower standard of butter quality, especially in the earlier years of its use. More recently, the quality of butter made under this system has been improved decidedly in certain regions.

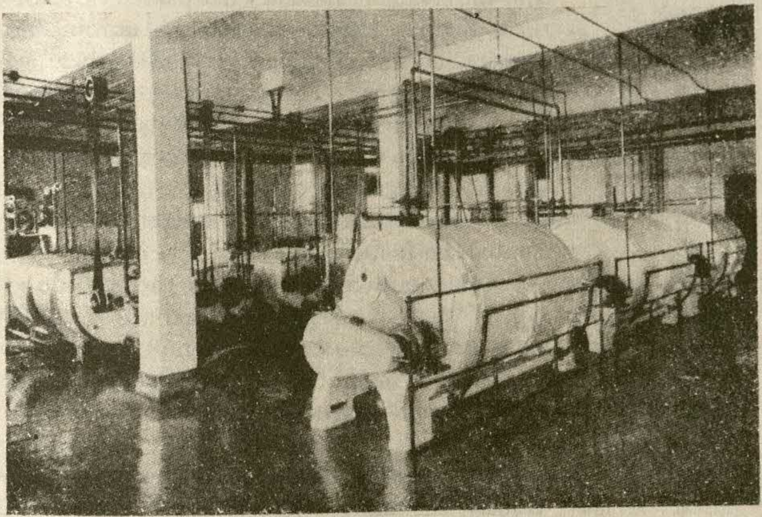


FIG. 57. **Inside view of a creamery.** The principal equipment of a small creamery is shown. The horizontal-coil pasteurizers are in the rear. The cream, after pasteurization and cooling, is pumped into the churn in the foreground. The churn and the pasteurizers are motor-driven. (*Courtesy of Cherry-Burrell Corporation.*)

There are indications, however, that the future will see the creameries of America turning again to whole milk as many did during the period of the Second World War when demands for skim-milk powder were pressing. In these plants, many of which have been in operation a number of years, it is possible for the management to receive whole milk, separate the surplus, sell sweet cream, churn all surplus cream, and manufacture from the skim milk and buttermilk concentrated products such as condensed or dry skim milk, cheese, or casein, all of which are readily marketed. It will be noted, therefore, that the creamery industry has passed through three distinct stages, apparently is now in the fourth, and entering upon the fifth stage of its development. These stages are: (1) the whole-milk creamery using gravity-creaming methods; (2) the creamery gathering cream, separated by gravity on the farm; (3) a return to the whole-milk creamery on the introduction of the factory separator; (4) a return to the cream-gathering plan with the introduction of the farm separator; and (5) a gradual turn back to the whole-milk creamery equipped to manufacture all types of dairy products and especially to make use of the by-products.

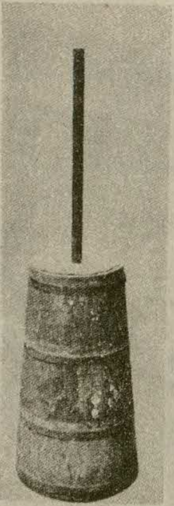


FIG. 58. An upright dasher churn. Churns of this type have been used on farms since colonial days but have largely disappeared in recent years. This churn was used on a Minnesota farm about 1850. (*Courtesy of Minnesota Historical Society.*)

Status of Farm Butter. As indicated previously, the manufacture of butter was exclusively an industry of the farm until past the middle of the nineteenth century. The introduction of the factory system of manufacturing butter, beginning in 1871, brought about a gradual evolution from farm-made to factory-made butter. That this shift in the industry was slow is indicated by the fact that, in 1900, about 66 per cent of the butter made in America was still a farm product. There was a steady development of the factory system, however, and, by 1920, the butter made on the farm was reduced to about 43 per cent of the total butter made in America; by 1940, this figure had been reduced to below 25 per cent and in 1950 to 12 per cent. The butter industry, therefore, followed the line of progress of many other industries which were introduced on the farm because of necessity.

The manufacture of cloth was at one time a task performed in the home. The art of weaving cloth at home is practically lost to the present generation of America. The same statement could be made concerning many other articles, such as tools, wagons, implements, shoes, etc., which once were made of necessity on the farm. Milk products were not the only food products formerly prepared and marketed from the farm and which now are prepared primarily under the factory system. The packing industry has greatly reduced the extent of butchering on the farm, and, likewise, breadmaking for home consumption has been greatly reduced during the past 25 to 50 years owing to the development of the modern bakery.

Composition of Butter. Butter consists primarily of milk fat. In addition to the fat, it contains water, salt (if salted butter), and a small amount of the milk solids-not-fat grouped under the term "curd." In 1912, the U.S. Department of Agriculture reported the composition of 695 samples of creamery butter gathered from 14 states as follows: 82.41 per cent fat, 13.90 per cent water, 2.51 per cent salt, and 1.18 per cent curd. An analysis of 1,000 samples of Minnesota butter, reported by the Minnesota Experiment Station in 1925, shows an average composition of 81.31 per cent fat, 15.35 per cent water, 2.31 per cent salt, and 1.03 per cent curd. According to federal food regulations, butter containing less than 80 per cent fat is considered illegal and is subject to a fine.

Processes Involved in the Manufacture of Butter. Since butter is made primarily under the factory system, it is intended briefly to discuss the processes involved in the manufacture of this product in the typical modern creamery or butter factory. The processes involved in the manufacture of butter in such an establishment may include the following: (1) separation of milk, (2) selection of cream, (3) neutralization of cream, (4) pasteurization of cream, (5) cream ripening, (6) churning, (7) packing and printing, and (8) marketing.

Separation of Milk for Butter Making. The ancient practice of churning milk for the production of butter still is followed in limited sections of the United States and abroad. Cream rather than milk is commonly churned for reasons of economy and efficiency. The typical farmer in the surplus butter-producing area of the United States has a relatively small herd. He does not feel that the amount of milk produced justifies daily delivery to the creamery, and the present plan of separating the milk on the farm will under these conditions probably continue until greater specialization results in a larger dairy herd. In those localities where the production of milk is on a larger scale, the milk now in some cases is delivered at the creamery where a power separator is used and the skim milk sold back to the farmer for feeding or made into such products as condensed or dry skim milk and buttermilk, cottage cheese, or casein. There are indications that this type of operation gradually will be introduced into those localities having a liberal milk supply. The advantages are the opportunity afforded to use the milk for whatever product may be marketed to the best advantage, the better quality of butter possible, and, especially, the complete utilization of the by-products. With a small dairy herd on the typical general farm, the skim milk can be utilized to good advantage for feeding calves, pigs, and poultry, but with a larger amount available it becomes impractical to keep sufficient animals to use the by-products. It then becomes a matter of economy to use the by-products for other purposes.

Types of Cream Used for Butter Making. Cream for butter making may be either sweet or sour. By far the largest percentage of butter in the United States is made from sour cream. A comparatively small amount is made from sweet cream. In either case a clean-flavored product is most desirable although not uniformly obtained.

The flavor of cream used for butter making is an important factor influencing the quality of the resulting butter. Many undesirable flavors may develop in cream. A cream may be sweet, yet possess an off-flavor which would yield, on churning, a butter of inferior quality. On the other hand, a cream may be acid, but possess a clean, fresh flavor and, on churning, produce a butter of high quality. These facts make it necessary to study the cause of off-flavors in cream so that it may be possible to make recommendations as to their prevention. Furthermore, it is desirable that cream intended for butter making should be divided systematically into grades.

Off-flavors in Cream. The general causes for the common off-flavors and odors that occur in cream may be classified as follows:

1. Off-flavors absorbed.
2. Off-flavors due to microörganisms or chemical action.
3. Off-flavors due to feed.

Absorbed Off-flavors. It is common knowledge that milk or cream will absorb volatile odors very readily. The average housewife is aware of this fact from practical experience. The producer of milk and cream also understands this possibility, yet many such flavors reach milk and cream by absorption from the air. One of the most common flavors found in milk or cream due to absorption is the characteristic "cowy" or "barny" flavor which is taken up by the milk from the air of the barn. Cream readily acquires odors from such sources as new lumber, smoked meats, decayed vegetables, cooking foods, and many others. These facts suggest the importance of keeping cream away from foreign odors of all sorts and, further, the need of keeping cream in a tightly covered container.

Off-flavors Due to Microörganisms or Chemical Action. The greatest percentage of the off-flavors occurring in cream are due to the growth of microörganisms. The number and types of the bacteria, yeasts, molds, etc., present will be dependent largely upon the organisms that were in the milk from which the cream was obtained. Some additional organisms may be picked up from dirty separators, cream cans, and other utensils, but the bulk of them will be those originally present in the milk. The predominance of any particular type after a given period of time will depend very largely upon the temperature at which the cream has been stored. Thus, if cream is kept at temperatures near 70°F. (21.1°C.), the souring types will prevail, while at higher temperatures, putrefactive types may gain the ascendancy.

Dairymen who are selling cream for manufacture into butter should be very attentive to measures of sanitation and refrigeration of their raw product. The eventual return for the cream will depend in a large measure upon the quality of the manufactured product and no manufactured article of high quality can be made from inferior raw products. The dairyman should exercise care in preventing contamination of the milk from the various sources of microörganisms previously mentioned. This is especially true of utensils, such as pails, milking machines, strainers, separators, cans, etc. Further than this, he must cool the cream, promptly and sufficiently, immediately after separating so that the growth of microörganisms may be checked as much as possible.

It is true, also, that, in many instances, contamination takes place in the creamery, and may be responsible for certain off-flavors developing in the finished butter. The most common flavor of cream due to bacterial growth is the sour or high acid flavor. As previously stated, however, acidity does not cause a serious off-flavor if the cream possesses a clean flavor otherwise. When sweet cream is desired for use as table cream or for sweet-cream butter manufacture, sour cream is considered undesirable. Along with the souring may come undesirable fermentations which produce distinctly objectionable flavors and odors such as putrid, bitter, cheesy, yeasty, musty, barny, and unclean. These flavors are chiefly the result of the action of the enzymes produced by various microörganisms. Many of them are to be attributed to a breaking down of protein in which case decidedly objectionable odors and flavors are to be expected.

No creamery operator can restore the quality of cream which has gone beyond the point of souring, and no dairyman can afford to continue practices which result in highly fermented or putrefied products. The microörganisms must be kept out of the cream as much as possible. Thereafter the raw product must be kept sufficiently cool to inhibit the development of those organisms which may be there inadvertently, and it must be delivered frequently to the factory, if the best returns are to be realized. Besides the flavors produced, because of the growth of bacteria and the subsequent action of their enzymes, there are certain defects of cream which are due entirely to chemical action. Among these may be cited the metallic flavor which may be caused by the action of lactic acid upon exposed metal, such as the iron in rusty cans.

Off-flavors Due to Feed. As a general rule, a healthy cow will produce milk free from off-flavors or odors. There are certain feeds, however, which, if consumed by the cow, will influence the flavor of her milk. Feeds, such as onions, garlic, ragweed, French weed, or fan weed, which give off volatile substances which find their way into the blood stream, will cause off-flavors in the milk. An excess of certain feeds, such as rye pasture, and some varieties of roots, may cause an off-flavor in the milk of an animal. In general, however, it can be said that feeds are responsible for very few of the off-flavors which occur in cream and that more sanitary methods on the farm will result in a decided improvement in the quality of the average cream.

Cream Grades. The general classification of causes for off-flavors in cream should be taken into consideration in attempting to formulate a system of cream grading. The question for the creamery operator to decide is: How serious are those flavors which are absorbed from the air, those due to bacterial and chemical action, and those due to feed? In general, it may be stated that off-flavors which are absorbed from the air are volatile and will pass off during heating and aerating. Furthermore, they do not increase in intensity. The most difficult flavors with which to deal are those due to bacterial development, chemical action, and feeds. The development of flavors due to bacterial action may be checked by pasteurization, but the objectionable products already formed are not removed. For this reason, flavors due to bacterial growth may be exceedingly difficult to overcome. This is particularly true of those off-flavors which are due to the decomposition of proteins of milk. Flavors due to feeds are likewise difficult to eliminate, especially when pronounced.

Cream Grading. Unfortunately, in the grading of cream there is no method by which the flavors of cream can be measured. The acidity can be determined easily by titrating with alkali solutions, using phenolphthalein as an indicator, but, in determining the presence and severity of flavors, many of which are far more objectionable than acidity, it is necessary to rely on the senses of smell and taste of an individual.

Cream grading is compulsory in a few states in America. The state of Minnesota was the first of the major butter-producing states to adopt a compulsory cream-grading law. In certain countries in Europe it is unlawful to sell anything but sweet cream. Australia has a law that prohibits the mixing of various grades. For a number of years very effective compulsory cream-grading laws have been in effect in Manitoba, Alberta, Saskatchewan, and other provinces of Canada. In most of the states in America the grading of cream is left to the individual buyer of cream. In these sections it is not uncommon for creameries to receive two grades of cream, a first and a second. Usually, about the only qualification for the first-grade cream is that it have a fairly clean flavor. Cream possessing an off-flavor is graded "second." Whether the cream is sweet or sour makes no difference in price, the result being that it is generally sour.

The acidity test often is used in the grading of cream. In some localities, a common practice is to place all cream in second grade when the acidity is higher than a definite percentage, the standard varying according to the ideas of those in charge of the business. In some localities, an acidity above 0.5 per cent places cream into a second grade. In other sections, the limit of acidity is still lower. The use of "visible mold" tests has also been introduced as a basis for grading.

In a few states in the United States, attempts have been made to require by law the grading of cream. For example, Minnesota, Iowa, and South Dakota have such legislation. These laws, in general, define four grades of cream: "sweet cream," "Number One," "Number Two," and "illegal cream." The "sweet cream" is defined as cream which is fresh, clean, and fine-flavored, with a titratable acidity of not to exceed 0.20 per cent. The "Number One" cream possesses the same characteristics but may have an acidity up to 0.60 per cent, while the "Number Two" cream may contain more than 0.60 per cent acid and/or contain undesirable odors and flavors in a moderate degree. Illegal or unlawful cream may be cream that contains dirt or other foreign matter that makes it unfit for human consumption.

The testing of cream for sediment in connection with the grading program has been given serious consideration by the butter industry. It is practiced in certain localities and is required by law in a few of the states.

The grading of cream is carried on in the so-called "receiving room" of the modern plant. Cream is weighed either in the cans in which it is delivered to the creamery or by dumping into a tank placed on a scale. Separate receiving vats or pasteurizers are provided for each grade of cream. It is for this reason that smaller creameries find it difficult to provide the necessary equipment required in grading cream.

Neutralization. The term "neutralization" is applied to the practice of adjusting the acidity of cream. The process consists of adding to cream a sufficient amount of a solution of an alkali, such as calcium oxide, calcium hydroxide, calcium carbonate, sodium bicarbonate, or magnesium oxide, to neutralize partially the lactic acid present. The object of neutralization is to permit the pasteurization of cream without danger of a loss of fat due to the coagulation of casein which takes place on heating cream of relatively high acidity. It further prevents the occurrence of curd particles in butter made from sour cream and doubtless improves the keeping qualities of butter made from such cream. It is obvious that neutralization has little place in the manufacture of butter made from sweet cream and should be considered as an expedient only in the manufacture of butter made from sour cream.

Pasteurization of Cream for Butter Making. Butter made from cream which has been pasteurized possesses much better keeping qualities than butter made from unpasteurized or raw cream. The significance of the keeping quality is evident in view of the fact that butter seldom reaches the ultimate consumer in the large cities before it is 2 weeks old and that much of it is from 2 to 6 weeks old before being consumed.

Three systems of pasteurization of cream for butter making are in general use; namely, the "vat system," the "flash system," and combination flash-and-vat system. The vat system consists of placing the cream in a vat, commonly termed "pasteurizer" and "cream ripener," in which the cream is heated to a temperature of 145°F. (62.8°C.) and held 30 minutes, after which it is immediately cooled. The period of holding may be shortened by increasing the temperature. For example, a temperature of 160°F. (71.1°C.) may be used for 15 minutes and 170°F. (76.7°C.) for 5 minutes. Temperatures lower than 145°F. (62.8°C.) are not sufficient to destroy the majority of bacteria, yeasts, and molds.

In the vat pasteurizer the cream is heated by a revolving coil through which hot water flows. This revolving coil also serves to keep the vat contents agitated during the heating process in order to prevent the cooking of the cream on the heating coils. The cream is cooled by passing cold water followed by ice water or cold brine through the coil. Sometimes the plan is followed of passing the cream over a surface cooler which consists of metal pipes through which water and brine may pass.

The flash system of pasteurization consists of bringing the cream rapidly, in fact almost instantly, to a relatively high temperature and cooling immediately. The temperature to which the cream is heated varies with the type of equipment used. A temperature of 180 to 185°F. (82.2 to 85.0°C.) is most common. The simplest design of flash pasteurizer for cream is a hollow drum with a double wall. A rapidly revolving agitator keeps the cream by centrifugal force in a thin layer against the outer wall of the drum as it passes through the machine. The heating medium between the two walls of the drum is high-pressure steam.

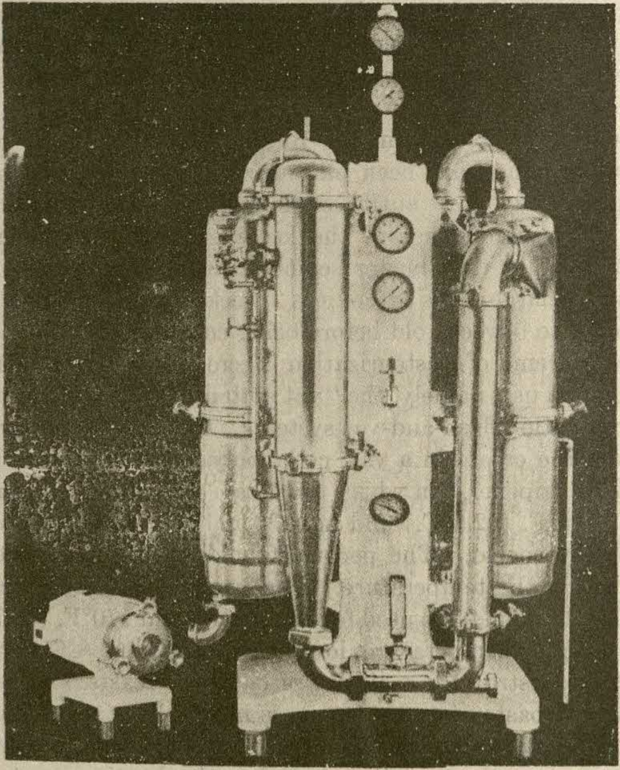


FIG. 59. Vacuum pasteurizer or "Vacreator" used for flash pasteurization of cream by direct contact of the cream with steam under low vacuum, steam distillation under intermediate vacuum, and cooling under high vacuum. The cream flow is continuous. (*Courtesy of Cherry-Burrell Corporation.*)

The temperature of pasteurization employed in other types of flash pasteurizers varies from 190 to 240°F. (87.78 to 115.56°C.). The simplest equipment of this type brings steam under pressure into direct contact with the cream. The process becomes more effective by providing for the partial cooling of the cream as well as the elimination of volatile flavors by discharging the hot cream into one or more vacuum chambers. The "Rogers System" of pasteurization is of this type. A device sold on the market as the "Vacreator" (see Fig. 59) employs somewhat the same principle with the exception that the cream is heated under partial vacuum. It is then passed through two vacuum chambers, where heat is removed before the cream is passed over a surface cooler.

When the flash system of pasteurization is employed, it is possible to arrange for a continuous flow of cream through the plant. The system is therefore best adapted for continuous operation and in plants with a large capacity.

The combined system of pasteurization consists of heating the cream to the desired temperature by means of a flash-type pasteurizer, after which it is passed into a vat where it is held for the desired period. It may then either be cooled in the vat or passed over a surface cooler.

The system of pasteurization which is used in a given creamery depends largely upon the volume of cream handled. Where a large volume is handled, the flash system has proved to be the more practical and more economical. When the flash system is used, however, the high temperature to which the cream is subjected results in a cooked taste of the butter. Although this cooked flavor will be hardly noticeable after the butter becomes a few days old, there are operators who prefer to use the combined flash-and-vat system of pasteurization. In those creameries handling a small volume of cream it is necessary that the plant operations be delayed until sufficient cream is delivered and, in such creameries, the vat system of pasteurization has proved the more practical.

Starters. The creamery industry understands that the term "starter" means a culture of desirable microörganisms in some nutrient material, which is usually milk. Starters have found an important place in certain branches of the dairy industry, especially for butter making, cheese making, and the preparation of fermented-milk beverages. The starters which are used in these various fields are somewhat different in character, according to the type of product to which they are to be added. Each of these will be discussed under the separate dairy products.

The culture employed in butter making usually is purchased by the creamery from some laboratory equipped to obtain and to propagate the proper types of bacteria necessary for desirable results. The bacteria in a butter culture are of two types, one of which has the function of fermenting the lactose of milk to produce lactic acid, which, in turn, curdles and coagulates the milk, the other, working in association with it to attack principally the citric acid of milk to produce volatile acids and products such as diacetyl which yield the desirable flavor and aroma of a good starter. Both of these types must be present if the best results are to be obtained. This combination of pure cultures is usually sent to the creameries in the form of milk cultures. The creameryman then inoculates a quantity (usually a quart) of milk (pasteurized at 180°F. (82.2°C.) or higher, for at least 30 minutes), with this culture, and sets it away at a temperature around 70 to 72°F. (21.1 to 22.2°C.) for several hours (ranging from 8 to 16 hours), until the bacteria have performed their duty so that the milk is coagulated and the desirable flavor and aroma produced. This starter is then said to have "ripened." It is cooled and set away until ready to use. This quart of starter is usually called a "mother starter" and, customarily, is carried in a glass flask or bottle through which the fermentation may be watched. This procedure of inoculating and ripening the "mother culture" is carried on day by day so long as the culture produces favorable results. When the operator desires a quantity of starter to add to cream to which he wishes to impart a delicate, desirable flavor and aroma, he adds a sufficient quantity of this "mother culture" to a batch of milk (which has been pasteurized above 180°F. (82.2°C.) for 30 minutes and cooled to 70°F. (21.1°C.)), and allows it to ripen at 70 to 72°F. (21.1 to 22.2°C.) for 8 to 16 hours until it is coagulated, after which it is cooled and added to the cream.

It is not possible to describe in words the flavor and aroma which a good starter should possess. This can be determined only by experience and keen observation. The main requirements are proper cultures of the bacteria, thorough pasteurization of milk, control of ripening temperatures and periods, and extreme cleanliness. Starter making is applied bacteriology in its finest sense.

The art of starter making is often beyond the capabilities of some creamery employees. Such workers may be content to use a substitute, such as a starter distillate or synthetic butter-flavor compound. Thus it is that some of the butter made in America is flavored with diacetyl, alone or in combination with other substances. Diacetyl is actually one of the compounds produced by a good starter and would be present in a starter distillate.

Cream Ripening. The term, "cream ripening," refers to the fermentation of cream intended for butter manufacture. The process often is called "souring" but is more than this term would indicate. Following pasteurization the cream is cooled to 68 to 72°F. (20 to 22.2°C.). At this point, there is added to the cream a quantity of starter such as that previously described. The amount of starter used depends upon several factors but usually ranges between 5 and 10 per cent of the total weight of cream.

By this procedure there is planted in the cream a large number of desirable bacteria. By holding the cream at about 70°F. (21.1°C.) for several hours, a fermentation takes place in which there is a development of acidity. A characteristic flavor and aroma will be imparted to the cream to be carried into the resulting butter. A number of years ago it was not uncommon to allow a development of from 0.5 to 0.7 per cent of acid in cream intended for butter making. The tendency, at present, is to limit the acidity to between 0.2 and 0.4 per cent, as it has been found that too high an acidity is detrimental to the keeping qualities of butter. When the desired acidity is reached, further development is checked by cooling. It must be borne in mind that the principal purpose of a starter in cream is to impart a desirable flavor and aroma, rather than develop a high acidity, and ripening may not be necessary where the starter itself has enough of the desirable flavor and aroma to be taken up by the cream immediately.

When butter was made under farm conditions, all cream was fermented more or less spontaneously before churning, and the public became accustomed to the taste of such butter. When creameries were established, better means for controlling the fermentation were devised, as indicated above. No starter is used in the manufacture of much of the butter made from sweet cream. Such butter is gradually being recognized on the market as "sweet cream" butter. Some of the finest butter made is that churned from sweet cream to which a small amount, 1 to 3 per cent, of good starter is added to the cream following pasteurization and cooling.

Butter Color. The natural color of butter varies under different conditions from a yellowish-white to a deep yellow. The yellow color, carotene, is entirely a plant product. Carotene is found abundantly in all green-plant tissue, but largely disappears as the plant becomes mature, and, to a less degree, when forage is dried in the process of haymaking. It is not present in appreciable amounts in grains. These facts are given to explain the close relationship which the feed of the cow bears to butter color. Some breeds of cows, for unknown physiological reasons, transfer more of the carotene from the feed into the fat. Under typical conditions of feeding, if no artificial butter color is used, the butter will be almost white in midwinter, very yellow during the weeks of fresh, luxuriant pastures, and, between these extremes, there will occur a gradual change from one to the other. This extreme change in color under natural conditions is decidedly objectionable to the consumer, who after being familiar with the yellow butter of the summer will refuse to use the light-colored butter of winter. As a result of this range in natural butter color, the practice started years ago of using artificial color to make possible a nearly uniform shade of color throughout the year. This practice continues, and butter made while the cows are on dry feed is practically all colored artificially. This is not looked upon as objectionable as the purpose is to regulate the color to a uniform point and is not in any way misleading. The coloring materials used must conform to the pure food laws, insuring that no harmful substance is used. The shade of color in butter to which people are accustomed determines the market requirements in that region. The eastern cities of the United States prefer butter with a light straw shade; in the southern states, a deeper yellow color is common; while on the western coast, an intermediate shade is most popular.

Carotene is used to a limited extent as a butter color abroad but is not used to any degree in the United States. Because of the fact that it has been shown that carotene is the mother substance from which vitamin A is formed, it is likely to become more popular as a coloring material for butter in the future.

The butter color most commonly used is either vegetable or one of the series of coal-tar dyes. The vegetable color used is a pigment from the seeds of the Annato (*Bixa orellana*), which does not supply carotene but a related pigment. Certain coal-tar dyes approved by the pure-food officials may be used. Both vegetable and coal-tar colors are prepared in a neutral oil which unites with the milk fat and for this reason the buttermilk does not show, to any appreciable extent, the presence of color.

CHURNING

Nature of Churning. When milk or cream is held at a favorable temperature and subjected to continuous agitation, the fat globules coalesce progressively, forming small granules of butter. A small quantity of other milk solids and of water is caught and held with the fat during the process, but the bulk of these constituents is separated from the fat and constitutes the product known as "buttermilk."

History does not record when man first discovered that fat could be churned from milk. All details of how the process takes place are none too well understood at the present day. Two theories have been advanced, one by Fischer and Hooker, and the other by Rahn. Fischer and Hooker maintain that, during the churning process, there is a reversal of the fat-in-water emulsion which exists in cream to that of a water-in-fat emulsion. Rahn holds to the view that the formation of butter is simply a packing of the globules into a compact mass and that water and air are enmeshed during agitation.

Normally, when cream is churned, it is observed that more or less foaming and whipping take place due to the incorporation of air, the cream increases in viscosity, and small grains of fat become visible to the eye. As churning proceeds, the cream undergoes a decided change in physical makeup: the cream appears granular; small granules of butter become more clearly defined; the cream adheres to the walls of the churn, and drops more like a semisolid mass; suddenly the "breaking" point is reached; butter "comes"; the granules of butter are distinct; there is a definite separation of the fat and serum of the cream. With continued agitation the granules become larger, and make the distinction between the buttermilk and the butter granules even more definite.

Exceedingly thin cream, or exceedingly high-testing cream, cannot be said to behave just in the manner above described.

Apparently, in the case of thin cream there are retarding factors involved; such cream fails to whip, the increase in viscosity is not so apparent, the "breaking" may be a gradual process, and the butter granules formed may be round and shot-like and fail to fuse after continued agitation. Thick cream of a high percentage of fat churns with very little foaming or whipping, and the period at which the cream breaks from the churn in a mass may be prolonged.

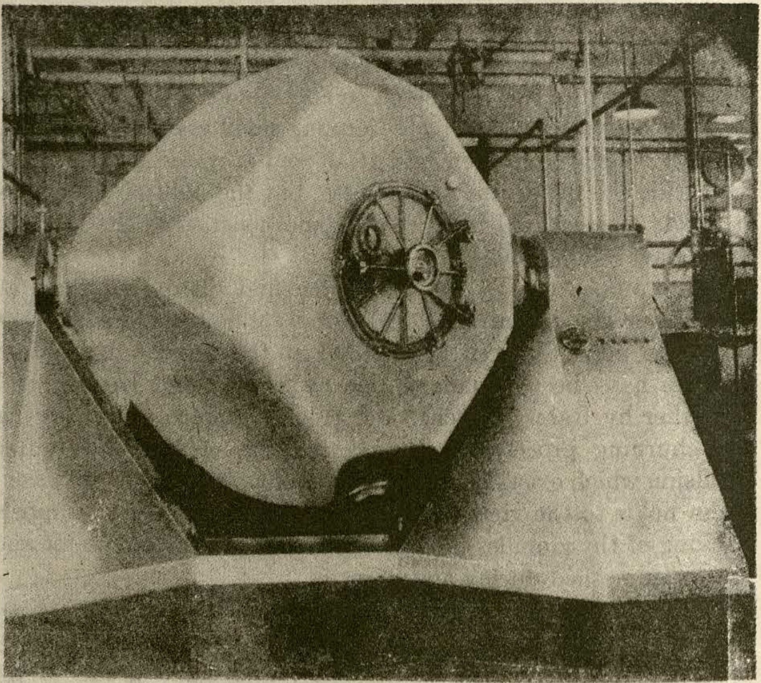


Fig. 60. A cubical metal churn, containing no inside working fixtures. Working of the butter is accomplished by operating the churn at a low speed which causes the butter to drop from a point near the top to the bottom with considerable force. Thus a kneading action takes place. (*Courtesy of Jensen Machinery Company, Inc.*)

The Churn. What constituted the first churn no one knows. It is known, however, that, the process of churning milk was known to primitive people. Records are available which show that milk was churned in bags made from animal skins. The Arabs tied such bags of milk to their saddles and dragged them over the ground or tied the bags to trees and swung them back and forth until butter was made. Later, earthenware containers served as churns. From these primitive churns developed the dash churn, the swing churn, the box churn, and the barrel churn, in common use until recent years. After churning in one of these last-mentioned types of churns, the butter was placed on a working table where it received the amount of working necessary to incorporate the salt and bring the butter to the proper texture. The introduction of the factory system of butter making stimulated the development of machinery for handling milk and making butter. The period of most rapid change was between 1890 and 1900, due to the introduction of the Babcock test and the cream separator. The same period saw the first use of the combined churn and butter worker which, since that time, has been in almost universal use in factories. With this equipment, the cream is placed in the churn, where the churning process is first completed, then the salting and working of the butter are carried out before the product is removed.

Construction of the Combined Churn and Worker. There are two types of combined churns and butter workers, namely, the "roll" churns and the "rollerless" churns. The chief parts of the combined churn and butter worker are the barrel or drum, the stand on which the drum is suspended, and the driving gears. In addition to these parts, in the case of the "roll" churns the workers are located inside the churn and are often termed the "rollers." The workers are constructed of large rectangular wooden beams, the corners of which are rounded and the four sides concaved. These are set in the churn lengthwise at the center, or at a point between the center and the inner wall of the drum. There may be one, two, or four rollers in the combined churn and butter worker, depending upon the make of churn. Along the inner wall of the drum and lengthwise of the churn, at carefully determined points, are set two or more shelves. These serve to lift and guide the butter during the working process to a point at which it will be pulled between the revolving worker and a fixed shelf in the single-roll churn or between the workers in the case of a two- or four-roll churn. If the principle applied in the common clothes wringer, where two revolving closely fitted rollers are revolving towards one another, can be imagined, a clearer conception of the principle involved in the case of the workers of the combined churn and butter worker, in use in the modern

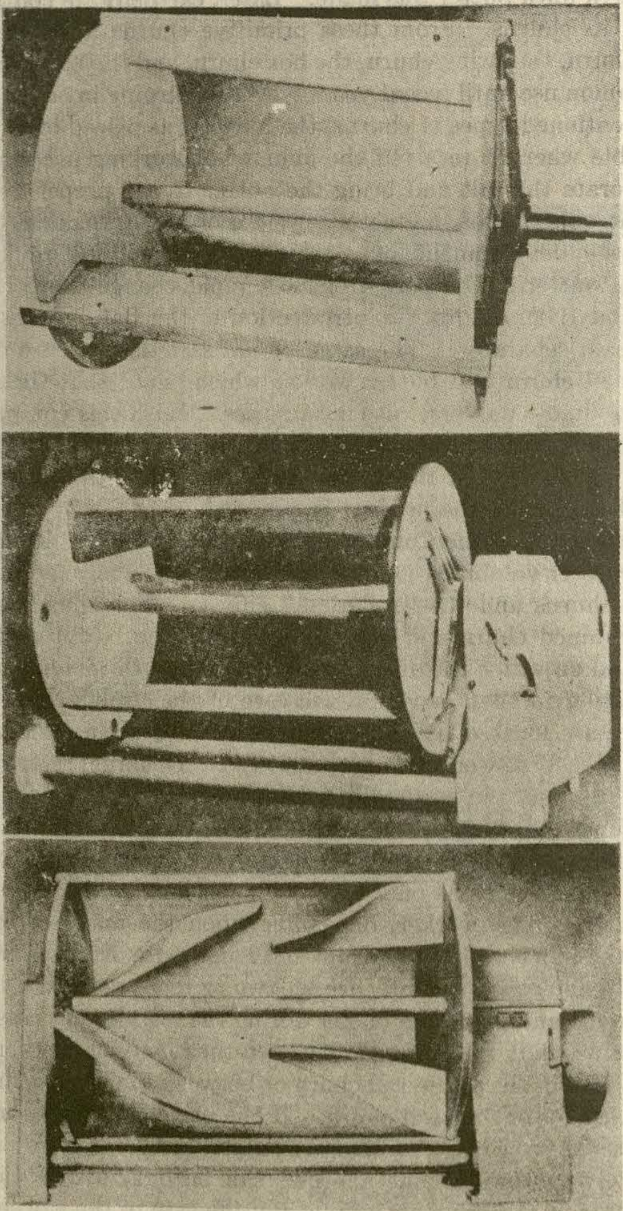


Fig. 61. Sectional views of three different rollerless churns. (*Courtesy of Creamery Package Manufacturing Company; Cherry-Burrell Corporation; General Dairy Equipment Company.*)

creamery, will be gained. These churns are constructed to churn and work from 50 to 1,000 pounds of butter. The smaller type is adaptable for large farm dairies.

In the "rollerless" combined churn and butter worker, as the term implies, no rolls exist. In general these churns are fitted with shelves on which the butter is lifted with each revolution of the churn. The butter may be dropped toward the center of the churn or it may be dropped across a bar that is set horizontally through the center of the drum. A box-shaped metal churn employs much the same principle but is provided with no inside fixtures.

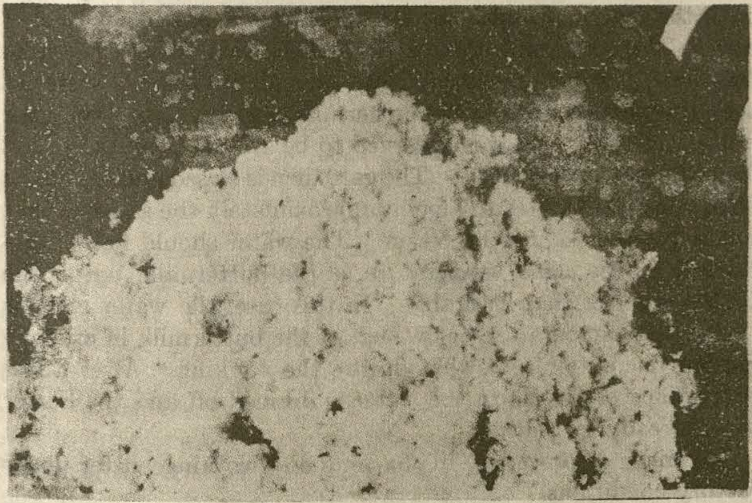


FIG. 62. The appearance of the butter granules after the churning process, ready for washing, salting, and working.

Churning Procedures. In order that butter shall not adhere to the wood with which it comes in contact, the pores of the wood must be filled with water. When a churn is used daily, or every other day, no difficulty is experienced regarding this point. All that is necessary is to rinse and cool the churn thoroughly by filling it partially with cold water and revolving for a few minutes, after which the water is withdrawn. If the churn is new, or is used at infrequent intervals, it should be soaked thoroughly by filling it with hot water at least 24 hours before the time for using, and rinsing it with cold water just prior to adding the cream.

The churn is filled from one-third to one-half full of cream. The cream, usually, is allowed to run through a strainer or filter, as it enters the churn, to assist in breaking any lumps of cream and to remove any particles of curd that might appear otherwise as white spots in the butter. The churn then is operated for a few revolutions and then is stopped, to relieve the air pressure by removing the small stopper provided for the purpose. This pressure may be due, in part, to the escape of gases in the cream but is due mainly to the expansion of the air in the churn caused by the absorption of moisture. The churn then is operated until the butter granules become the size of a pea or a kernel of corn. The buttermilk then is allowed to drain thoroughly from the churn. When this is complete, a small quantity of water at the same temperature as the buttermilk may be poured over the butter granules until it is observed to be almost clear as it flows from the gate of the churn. The gate then is closed and the churn filled with wash water to a point approximately the same as that originally reached by the cream. The water should be approximately at the same temperature as the buttermilk, unless the butter is softer than desirable. In this case, the water may be cooled to a temperature below that of the buttermilk in order to harden the butter somewhat during the working. After a few revolutions of the churn the water is drained off and the butter then is ready for salting.

Summary of procedure in churning and working butter under factory conditions:

1. Prepare churn. Wash with hot water and follow with cold water.
2. Place cream in churn.
3. Add butter color, if required, according to shade desired.
4. Start churning and continue until butter granules reach size of peas or popcorn.
5. Drain buttermilk from churn.
6. Rinse buttermilk from walls and ends of churn and from butter by sprinkling with water approximately of the same temperature as buttermilk.
7. Wash butter by adding to churn approximately the same amount of water as there was cream in the churn at the beginning. Water should be near the temperature of the buttermilk, slightly colder if it is desired to firm the butter, or slightly warmer if butter granules appear too firm.

8. Drain wash water from the churn.
9. Sprinkle butter granules with salt if required.
10. Work butter sufficiently to bring the butter into a compact mass.
11. Stop the working process, take a representative sample of the butter from the churn, and make the moisture analysis.
12. Continue working process, permit water from butter to escape from churn if moisture analysis indicates high moisture. If moisture analysis indicates low moisture (below 15.8 per cent), sufficient water should be added to bring moisture in butter to desired amount. Work butter until it has a firm, waxy body.
13. Remove butter from churn.
14. Wash churn.

Factors Influencing Churning. It is desirable that the churning operation consume the least amount of time compatible with a minimum fat loss in the buttermilk. Further, it is desirable that butter have a firm, waxy body and not appear as a slushy, salvy mass. As a general rule, any condition which tends to make churning easier or which results in the formation of butter granules in a comparatively short period causes a relatively high fat loss in the buttermilk and a slushy, salvy butter at the churn. Likewise, it may be stated generally that any condition which results in the prolongation of the churning period results in comparatively lower fat losses in the buttermilk and a butter of a more firm and waxy appearance. It appears, therefore, that the ease with which cream churns, the time required to churn, and the condition of the butter are closely associated. The factors involved are discussed in later paragraphs.

Temperature of Cream. Temperature is the most important factor concerned with churning. In milk, milk fat occurs in the form of globules which are in a liquid condition, as the milk comes from the cow at a temperature of close to 100°F. (37.8°C.). When the temperature is reduced during the interval before churning, the fat globules become firmer. For churning to take place, the temperature of the cream must be such as to allow the fat globules to coalesce. The colder the cream, the longer the period required to complete the churning process. If too cold, the fat globules are hard and may not adhere, making churning almost, if not quite, impossible. If too warm, the churning may take place quickly, but the butter obtained will be soft in texture and will contain too much of the milk serum. When all other factors remain constant, sweet cream should be churned at a temperature which will require from 50 to 60 minutes for completion. For sour cream, a period of 30 to 40 minutes gives equally good results, for reasons explained elsewhere. The competent butter maker regulates the churning temperature mainly according to the time required. If the time required for churning considerably exceeds the limits for several days in succession, the competent operator analyzes the situation the best he can and, if there appears to be some explanation, for example, a change in feed due to the approach of winter, he modifies his churning temperature accordingly. As summer approaches and the cows go on pasture, the reverse condition occurs with the difference that the change is more sudden. Typical churning temperatures under factory conditions are 48°F. (8.9°C.) in summer, increasing to 54 to 56°F. (12.2 to 13.3°C.) in winter.

Experience teaches that cream should be held at or below the churning temperature for a period of at least 2 hours before the churning process begins. If cream is cooled rapidly to the churning temperature from a point considerably above, the churning takes place quickly and is accompanied by a soft condition of the butter and an excessive loss of fat in the buttermilk. Evidently, time is a factor in relation to the effect of temperature upon the physical condition of the fat.

When normal churning is completed the temperature of the butter and the buttermilk is from 4 to 8°F. (2.2 to 4.5°C.) higher than that of the cream at the beginning. The rise in temperature is the result of at least three factors. Some heat is absorbed from the churn itself due to the fact that the churning is carried on in a room considerably warmer than the cream. A second factor is the friction within the churn, and a third, the release of latent heat by the solidification of those fat globules still in the liquid condition. This last factor is most important when the cream has been cooled rapidly from a high temperature and when the period of holding before churning has been short. The temperature of the cream at time of churning and the period and temperature of holding previous to churning are factors which are closely related to the time of churning. There is also an interrelationship best understood by the results of an experiment.

a. Under certain conditions it was found that cream could be churned efficiently (minimum loss of fat) at 48°F. (8.9°C.) in from 40 to 50 minutes. This cream had been held 12 hours at the churning temperature.

b. A portion of the same cream churned in 30 minutes with a decidedly higher loss of fat after it had been held at the same temperature 48°F. (8.9°C.) for 2 hours.

c. A third portion cooled to 38°F. (3.3°C.) for 2 hours then slowly warmed to 48°F. (8.9°C.) churned in practically the same time as (*a*) and with the same efficiency. It is clear in (*c*) that the lower cooling temperature served the same purpose as the longer period of holding in (*a*). Had the churning of (*c*) been begun at a temperature of 38°F. (3.3°C.) the point at which it was held, the time required for churning would have been greatly prolonged. In fact the churning probably would not have taken place until the temperature increased by friction to the same point as that at which the process was complete in (*a*).

In practical creamery operations these facts are used constantly. If cream must be churned quickly after reaching the factory to make room for more, the operator lowers the temperature previous to churning in proportion to the interval before churning must begin. If the cream is to be held 12 hours or longer it is cooled only to the churning temperature. The churning temperature also may be varied to suit the time of holding. If, for example, 48°F. (8.9°C.) is the usual churning temperature and for some reason the churning must begin after holding the cream only 1 hour, the correct procedure is to cool the cream as quickly as possible to a point 15°F. (8.3°C.) or more below the usual churning point and to begin churning with a temperature of at least 5°F. (2.8°C.) below the usual point.

Composition of Milk Fat. It has been pointed out, previously, that the melting point of the milk fat is a factor influencing the ease with which cream will churn. In the fall and winter months milk fat contains, as a result of the character of the feed received by the cows, a larger proportion of the harder fats and is more difficult to churn unless the temperature of churning is raised. Likewise, in the spring months butter may appear as a slushy mass in the churn unless a lower churning temperature is used. This soft condition is due to the presence of a larger proportion of fats with low melting points as a result of the change in the diet of the cows to pasture grass. Other individual feeds, especially cottonseed meal, exert a specific effect upon the hardness of the fat and, for this reason, the churning temperature may vary from one locality to another, depending upon the prevalence of certain feeds. It is apparent from what has been given that these conditions may be met by adjusting the churning temperature.

Influence of Size of Fat Globules. The size of fat globules is not a factor of any practical importance to the creamery. It is to be considered, however, in comparing the ease with which cream churns in different localities, and at various seasons of the year in the same locality. Other conditions being equal, large fat globules gather into butter granules more easily and more quickly than small ones, and the time required for the process of churning is somewhat less for this reason. The effect of this factor may be observed in some localities where certain breeds predominate, or may be tested experimentally where the milk of different breeds is available. The small fat globules characteristic of milk produced near the end of the lactation period are one factor in causing the difficult churning so often experienced under farm conditions. Where butter is made under farm conditions, the cream may be from a few cows only and these advanced in lactation. In the creamery, the cream represents the product of so many cows that conditions in the milk of some that might cause difficult churning are counteracted by others.

Acidity as a Factor. When the acidity of cream develops to the point of precipitating the casein, it churns more readily than the same cream does at a lower acidity. In order to secure the same efficiency in churning, a somewhat lower temperature must be used for sweet cream, while a longer churning period also must be expected. In factory practice, it sometimes happens that a suitable temperature has been determined by experience for churning sour cream under the existing condition, but when sweet cream is churned at the same temperature, considerable loss of fat in the buttermilk results. The important fact to consider in churning sweet cream is to use a lower temperature and a churning period somewhat longer than for ripened cream from the same source. The easier churning of sour cream is due to the changed physical condition of the cream as a result of the presence of acid. Although sour cream may appear more viscous than sweet, the facts are that the souring lowers the viscosity of the serum due to the coagulation of the casein. The precipitated casein gathered into masses of various sizes offers less resistance to the contact of the fat globules than when the casein is in the normal colloidal solution.

Viscosity of Cream. The viscosity of the cream is a factor concerned with churning, especially in relation to the time required to complete the process. Extreme viscosity may result in sufficient cream adhering to the churn, especially the barrel type, to reduce the agitation and thus prolong the churning. A viscid cream also incorporates great volumes of air and, when this condition occurs, the fat globules are not brought together readily and churning is delayed.

The viscosity of cream increases with age, also with the development of acidity up to the point where precipitation of the casein begins after which it is again reduced. The composition of the milk serum is perhaps the most important factor. Changes in this portion of the milk accompany advanced lactation and, to some extent, changes in the feed of the cow.

Richness of Cream. A cream with a high fat content will churn more quickly than one with a low fat percentage. A low fat content, for example 20 per cent, results in a longer churning period and a higher loss of fat in the buttermilk. Nothing is gained by going to the other extreme. When the fat content is 40 per cent, or above, a fat loss often occurs because of unchurned cream adhering to the walls and end of the churn. In a small churn, for example the barrel type, as used on the farm, cream with a high fat percentage may adhere to the churn to the extent of making churning almost impossible. From 30 to 35 per cent fat in the cream gives the best results both from the standpoint of time required for churning and that of efficiency in recovering the butter fat from the buttermilk. The more difficult churning of thin cream is caused by the larger proportion of milk serum, which acts as a cushion, keeping the fat globules from coming together.

Fullness of Churn. The amount of agitation to which the cream is subjected will influence the time required for the butter granules to form. A typical creamery churn gives sufficient agitation when it is filled from one-third to one-half full. If filled more than half full, the period of time required for churning will be increased. It can be expected, when a given churning temperature results in butter forming in from 40 to 50 minutes with the churn one-half full, that the same cream, at the same temperature, will require from 4 to 6 hours to churn when the churn is two-thirds to three-fourths full.

Speed of Churn. The amount of agitation is also influenced by the speed of the churn. It is essential that the cream be given the maximum amount of agitation as the churn revolves. Should the churn be turned too fast, the force of gravity is overcome by centrifugal force and the cream follows the motion of the churn, receiving little or no agitation and, thus, churning is prolonged. The hand-barrel or power churn should be turned at a speed slightly under that at which the centrifugal force might overcome the force of gravity. This will depend to some extent on the diameter of the churn used.

Fat Losses in Buttermilk. It is important that the churning operation be conducted with the minimum loss of fat in the buttermilk. As pointed out previously, the factors influencing churning are closely associated with these losses. It would appear that cream must be subjected to sufficient agitation to insure the gathering of most of the fat in granular form. Other factors being the same, when the conditions of churning are such that the butter churns in a relatively short period, it is the general rule that the percentage of fat in the buttermilk will be high. When churning conditions are such that a prolonged churning is required, the fat losses appear to be relatively low. Thus, it happens that, when a relatively high churning temperature is used, the cream churns more quickly with higher fat loss in the buttermilk than when cream is churned at a low temperature. The temperature at which cream is churned, however, is not the only factor involved. Cream must be held at a temperature sufficiently low to ensure the solidification of the fat globules and, since the solidification of fat is a gradual process, it is essential that the cream be held at a low temperature for the period preceding churning. It was previously stated that cream should be held at the churning temperature, or below this temperature, for 2 hours or more, to permit the fat to chill thoroughly. It is possible to churn cream so efficiently that only a trace of fat can be detected in the Babcock-test bottle, following the Babcock procedure. High losses of fat, amounting to buttermilk tests of from 1.0 to 5.0 per cent, or above, may readily occur when too high a churning temperature is used, or when a chilling period preceding churning is too short.

Each of the other factors affecting churning may be responsible for wide variations in the percentage of fat in buttermilk, but none is so pronounced as the effect of temperature. For example, there is a slight increase in the fat loss in buttermilk when the churn is too full, in which case, a prolonged churning period also results.

There is a smaller loss of fat in buttermilk when sour cream is churned than is experienced in churning sweet cream under similar conditions. When the churning temperature is lowered and the churning process is prolonged, however, sweet cream can be churned as efficiently as sour cream. It is apparent from the above statements that it is impossible to churn all the milk fat from cream.

Difficult Churning. The creamery operator seldom experiences any difficulty in getting the cream to churn. The explanation is that the cream comes from a large number of sources, and, furthermore, under factory conditions it is possible to control all conditions carefully. On the farm, however, churning difficulties are common, especially during the winter season. Sometimes butter is secured only after several hours churning, occasionally not at all. The cream may foam until the churn is full. These especially severe cases of difficult churning often are associated with an abnormal taste which develops in both the milk and the cream after standing 12 to 30 hours. This taste is described as rancid, bitter, or stale and has been found, by scientific study, to be due to the action of the enzyme, lipase, in the milk. The action of the enzyme on the fat is partly responsible for the trouble in churning.

The troubles which confront the farm butter maker are the result of a combination of some of the factors already described. With one restricted source of supply it is not unusual for all cows to be advanced in lactation. This results in small fat globules and a large proportion of hard fat; furthermore, the milk serum from cows near the end of lactation is high in protein, causing a higher viscosity in the cream. These unfavorable conditions often are intensified by failure, on the part of the butter maker, to handle the cream so as to develop the proper acidity. Often little attention is given to the temperature of the cream at the time of churning. The remedy is, first of all, to induce the proper development of acid in the cream and then to obtain a suitable temperature at churning. These measures may be ineffective in some cases. The addition of cream from a fresh cow usually brings the desired result. Another procedure having some merit, during periods when difficult churning occurs, is to mix the cream, fresh from the separator, with sufficient warm water to bring the mixture to a volume approximately that of the original milk, and reseparate. This dilutes the milk serum and reduces the viscosity.

Overrun in Butter Making. The Babcock test shows the amount of milk fat in cream. When butter is churned from the cream some moisture and curd are incorporated. Later, salt is generally added. As a result, the yield of butter exceeds the amount of the fat. This excess over the fat is called the "overrun." For example, from a batch of cream containing 80 pounds of fat a yield of 100 pounds of butter may be obtained. The 20 pounds of butter in excess of the fat is the overrun. The overrun generally is expressed in terms of percentage. In this case 20 (the overrun in pounds) is easily found to be 25 per cent of 80 (the original amount of fat), and the creamery operator, therefore, records his overrun as 25 per cent. The amount of overrun varies with the composition of the butter and the skill of the operator. On account of the possibility of incorporating an undue amount of constituents other than fat, legal standards have been fixed by national and state laws. At present, federal regulations have established a minimum of 80 per cent of fat. Some states also fix a maximum moisture content, usually 16 per cent. The salt content is controlled by the market demand. It is exceedingly important that the creamery operator have the skill required to secure the maximum overrun and still keep within legal limits for the composition of the butter. An overrun of about 23.5 per cent based upon the cream test is as high as can be expected. A low overrun results from losing an undue amount of fat in the buttermilk as the result of improper control of the conditions of churning or failure to incorporate sufficient moisture.

Salting Butter. Salt is added to butter to prolong its keeping quality and to impart a pleasing flavor. The salt used in butter must be of a high degree of purity, of fine grain, and readily soluble. The amount of salt added to butter depends upon the market requirements. The salt content of typical butter, as found on American markets, ranges from 2.0 to 3.5 per cent. The market requirements vary from a demand for butter with no salt, to one containing as high as 5 per cent of salt. This variation is associated, partly, with the grade of the product and, partly, with the locality. The creamery operator adds to butter as much salt as the market which he supplies will tolerate. Salt is cheaper than milk fat and every ounce of salt incorporated into butter replaces an equal amount of milk fat. Market requirements for salt may, therefore, better be termed "salt tolerances."

The modern combined churn and butter worker permits the salting of the butter granules, while they are in the churn, immediately after the churning process is completed, and after the buttermilk has been allowed to drain thoroughly from the churn. The amount of salt for a given churning is calculated on the basis of the pounds of fat in the churn. To secure a salt percentage of 2.5 per cent, the operator should add approximately 2.75 pounds of salt per 100 pounds of fat in the churn, as calculated from the test and weight of the cream. A higher salt content in the finished butter calls for a corresponding increase in the amount added. According to the preference of the operator, dry or wet salt is sprinkled evenly over the butter granules or in a trench formed in the butter by means of a butter ladle after working the butter for a few revolutions in the churn. The next step is the working of the butter.

Working the Butter. The object of working butter is to bring the granules into a compact mass, distribute the salt evenly, and expel the surplus buttermilk. This important part of the butter-making process must be regulated so that the finished butter will have the proper composition and the desirable texture or body. The skillful creamery operator determines, by suitable methods, the amount of water and fat in the butter at one or more intervals during the working process. With this information at hand he removes the surplus water by additional working or increases it by adding the water necessary to give the uniform desirable composition. When the working is completed, no free moisture should be visible. Some butter makers judge solely by the appearance of the butter when the working should be stopped.

When the combined churn and worker is used a common practice is to operate the machine for the number of revolutions which experience has shown to be necessary. The results are checked by an examination of the butter. The body of the butter should be close, firm, and waxy. The salt should be distributed uniformly and the water droplets evenly dispersed. Uneven distribution of salt resulting from underworking is associated with an uneven color in the butter known as "mottles." This condition results from relatively large droplets of water in such butter being drawn toward points of high salt concentration, which causes a deeper yellow color in these portions. Overworking of butter, in the normal condition of hardness, results in a dull color and a salvy body. When butter in a soft condition is overworked an objectionable condition known as "greasy butter" results.

The Continuous "Churn." Efforts have been made to develop equipment which would carry on the churning in a continuous operation. The efforts to develop a continuous method of churning are reflected in the development of the "Fritz" and the "Alfa" processes in Germany, the "New Way" process in Australia, the "Senn" process in Switzerland, and methods embodied in the processes of the Creamery Package Manufacturing Company and the Cherry-Burrell Corporation of the United States. In the opinion of the authors, these churns are in the stage of development and until their worth is proven their use will be limited. The Cherry-Burrell Corporation has advanced to the stage of development where the company is making commercial installations in the United States. The first churn successfully operated by this process was in the Sugar Creek Creamery of Danville, Ill.

By the Cherry-Burrell Corporation process, cream is drawn from a holding tank and pumped into an "agitator-beater" where the fat is partially destabilized. The cream then passes through a specially constructed separator from which is discharged a product with a milk-fat content of 86 to 90 per cent. This high-fat cream is then pasteurized. The pH, color, water, and salt content are all standardized while in a liquid state and at a temperature of 115 to 120°F. (40.5 to 48.89°C.) The liquid, milk-fat concentrate is then pumped through specially designed chilling equipment. From this point the product is passed through a "texturator" where it receives a final working to form butter. The butter is ready for printing or packaging as it leaves the machine.

Marketing of Butter. Butter is not a product of thickly populated urban districts but of those regions removed some distance from such centers. Fully 75 per cent of the butter produced in the United States is manufactured in the Middle Western states. This means that the greater part of the butter supply goes through central markets. Furthermore, the production of butter varies widely at different seasons, while the consumption is quite constant. This makes it necessary to provide for the holding of the surplus in cold storage until the immediate supply falls below the demand. Butter dealers or brokers have established themselves at the market centers. To these dealers many creameries ship their product, in accordance with a contract, or, in some cases, to be sold upon a commission basis. The wholesale dealers maintain warehouses, cold-storage facilities, office personnel, and the equipment necessary to conduct a business of this character. The product is sold to

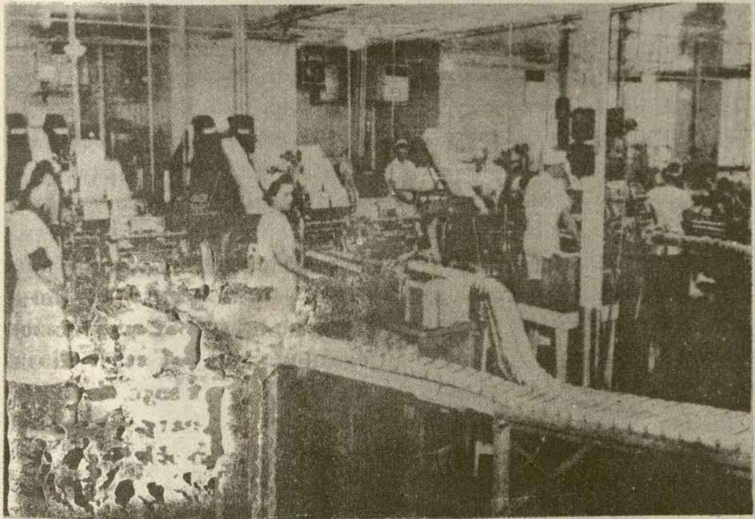


FIG. 63. Printing, wrapping, and cartoning butter. The battery of machines cuts, prints, wraps, and places the butter in cartons automatically. Quarter-, half-, or full-pound prints may be handled. The attendants simply regulate and check the operation of the machines. (*Courtesy of Land O'Lakes Creameries, Inc.*)

the retailer or to other smaller jobbers who distribute it to the retailer. The wholesale dealer buys his butter mainly in tubs and often sells it to the retailer in the form of prints.

Butter may be held in cold storage by any one who is so inclined and who has the necessary capital. In addition to private cold-storage plants, there are abundant facilities available in every large market where, by the payment of the standard charges, any desired amount of butter may be stored. Some wholesale dealers also store butter at times, but many who take part in this speculation have no other relation to the butter industry. Butter goes into storage chiefly during the months of May, June, and July, and is removed whenever the market price reaches a point where the butter can be taken out and sold at a profit. Most of the butter stored is not held longer than 8 or 9 months. Some deterioration in quality often occurs, the extent depending upon the quality of the cream used and the methods of manufacture followed. Butter kept in storage has not been injured in the least for human food, and the plan of storing the surplus for times of scarcity is of decided advantage to both the producer and the consumer.

Within the last decade a few creameries have developed efficient marketing systems within their own organizations. These creameries not only sell the butter manufactured in their own plant or plants but may contract to sell butter made in other plants. By maintaining warehouses and a marketing organization in the large market centers, these concerns are able to market to advantage all the butter which they manufacture and permit smaller plants, with a less efficient organization, to realize higher returns.

Market Terms. The following are some of the terms applied to butter found on the market:

Sweet-cream Butter. Butter made from sweet cream, to which no starter has been added. The cream is generally pasteurized.

Ripened-cream Butter. Butter made from ripened cream. A starter has been added to the cream.

Creamery Butter. Butter made in a factory from cream produced on a number of farms.

Sweet Butter. Often refers to butter which contains no salt.

Unsalted Sweet-cream Butter. Butter made from sweet cream to which no salt is added.

Unsalted Butter. Butter to which no salt is added.

Salted Butter. Butter to which salt is added.

Whey Butter. Butter made from cream separated from whey which results in the manufacture of cheese made from whole milk.

Farm or Dairy Butter. Butter made on the farm from a single herd, generally from unpasteurized cream.

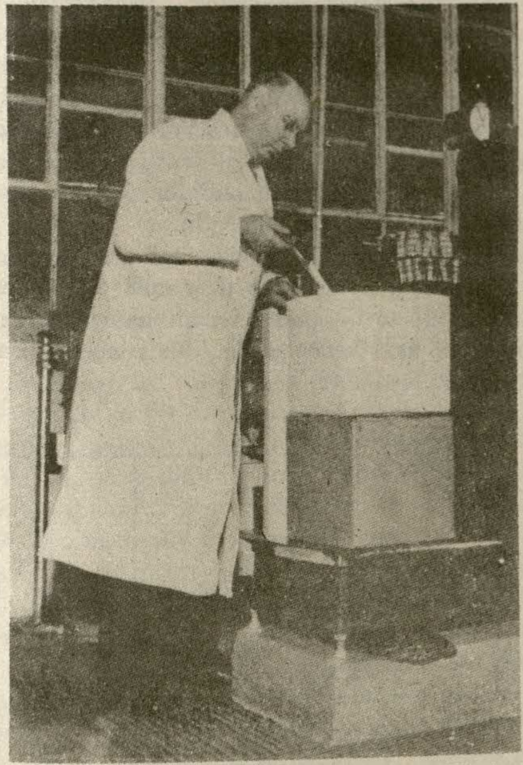


Fig. 64. The grading of butter by federal inspectors. The inspector uses a butter trier with which he removes a long plug of butter from the tub or box. He then examines the plug for aroma, taste, body and texture, and color.

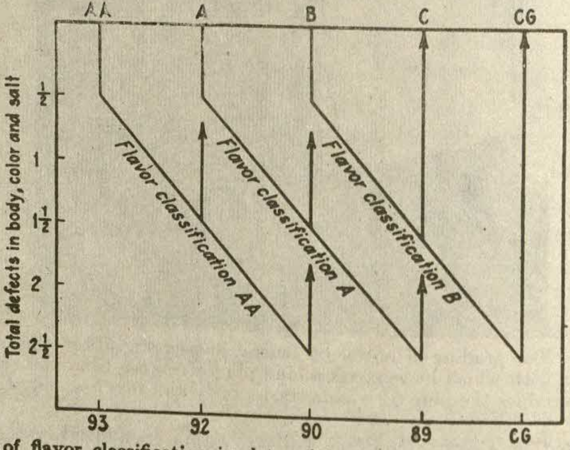
Renovated or Process Butter. Butter which is melted, refined, and reworked. A government tax is levied on this type of butter and all plants manufacturing it are subject to government inspection.

Packing Stock. Butter which is unsuitable for market purposes, ordinarily used for making renovated butter.

Market Grades of Butter. Creamery butter is graded on the market according to its flavor, body, color, and salt content.

For many years graders of butter used a score card similar to that which has been used in educational contests and to which reference is made below. The custom of expressing the grade of butter in terms of a numerical score was unsatisfactory because the average housewife had no conception of its meaning. Through the years the grading of butter for market purposes has become a highly technical profession. It has become possible also to place butter into grades that are understandable to the buying public. This has been done by adopting a letter system of grading where butter of various qualities can be definitely defined. The specifications for United States grades of creamery butter proposed by the Agricultural Marketing Service of the U.S. Department of Agriculture and for use by government butter graders are given in the Appendix.

In grading butter, flavor is given first consideration. The above specifications provide that a sample of butter can be criticized and cut up to 1½ points for mechanical defects before is placed to the next lower grade. This is graphically illustrated in the chart below.



Influence of flavor classification in determining top grades of creamery butter showing importance of flavor in determining grade. (*Courtesy of Creamery Journal.*)

A sample in one flavor classification can lose up to 1½ points for mechanical defects before it drops to the next lower grade. It can lose 2½ points before it drops two grades.

The butter score card used in teaching students and in educational contests is as follows:

Flavor	45 points
Body	25 points
Color	15 points
Salt	10 points
Package	5 points
	100 points

Although, according to the score card, butter may score 100 points, in practice it is assumed that no butter is perfect and the perfect score is never given. Butter seldom is scored more than 93 to 94 points on the market.

Butter Defects. *Flavor.* The average consumer is not concerned with all the defects that the critical judge of butter may look for in butter. Flavor receives the special attention of the consumer and, for this reason, flavor is given the largest number of points on the score card. Butter showing irregular color, a condition described by the butter man as "mottled," also is very objectionable to the consumer.

While expert judges will agree rather closely in judging the flavor of butter, it is difficult to describe either the desirable or undesirable flavors. Flavor cannot be measured chemically and can be described only by comparison with some well-known flavor possessed by other substances. Certain flavor defects sufficiently characteristic to allow of some unanimity in describing them are fishy, rancid, cheesy, metallic, yeasty, lardy, bitter, or cooked. The causes of these flavors are fairly well understood as the result of extensive investigations in America and abroad.

Many lots of butter show defects in flavor equally objectionable but which cannot be classified so definitely. Judges follow the custom of using various descriptive words that may or may not have any relation to the cause which the term may suggest. Often the same flavor might be described in different terms by each of several judges. Among the terms of this class are "unclean," "fruity," "stale," "barny." When a low score is given and such terms are used, there is little question regarding the quality of the butter, but neither the score nor the descriptive terms are of much assistance to the butter maker in finding the cause of the poor quality.

Body Defects. By the term, "body," is understood the general character of the physical makeup of the butter. The word "texture" was formerly in common use with the same meaning. Butter should be reasonably firm, close textured, and of a waxy appearance. A weak-bodied butter is a butter which does not stand up readily at ordinary temperatures; a greasy texture indicates a butter with the appearance of grease; a salvy texture is a butter which has been worked until the grain is destroyed entirely. Butter from which water readily leaks is said to have a "leaky body." Other body defects are crumbly, sticky, and mealy.

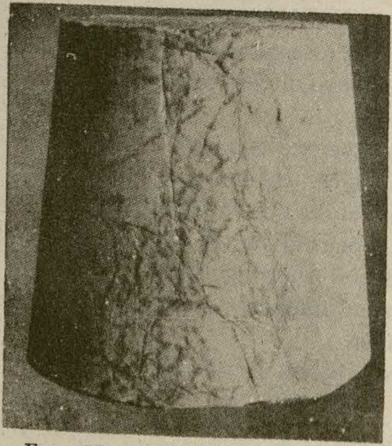


FIG. 65. Mold on butter. Mold sometimes develops on butter as shown in this illustration of butter as it appeared when removed from the tub. If the mold is not growing through the butter but only on the surface, it may be removed by scraping, and the unaffected butter sold. If the mold has penetrated the butter, the product is classed as packing stock and sold at a low price.

Color and Salt Defects. Either too much or too little color is objectionable. The market, in general, requires a butter of a light straw color. When the color of butter is distributed unevenly or when light streaks show between darker streaks of yellow, butter is said to be "mottled." This defect is due to an uneven distribution of water through the butter, associated with an uneven distribution of salt to which water may be attracted. Distinctly colored areas may appear on the surface due to the action of bacteria, yeasts, or molds. Salt defects in butter may be designated as too high or too low salt content. Butter in which the salt content is so high that undissolved salt occurs throughout the mass is often spoken of as being "gritty."

Farm Butter Making. The same principles given for butter making under factory conditions apply equally to making butter under farm conditions. Due to the small quantities involved and the limited amount of equipment available, however, the practices differ in many respects. On the farm, due to the small amount of cream, it may not be practical to churn oftener than twice a week. To keep cream longer than this without pasteurization will nearly always result in inferior butter that will deteriorate rapidly. The proper procedure is to cool the cream immediately after separation and keep it cool until the day previous to churning when it may be warmed to room temperature for souring and again cooled to the churning temperature for at least 2 hours before churning begins. The warming of the cream to encourage souring may be omitted if too great difficulty in churning is not encountered by such a procedure. The use of a starter is seldom practiced under farm conditions.

A floating dairy thermometer always should be available to use in regulating the temperature. No one can guess the temperature with sufficient accuracy. Prolonged churning often results from failure to observe the important precaution of having the cream at the proper temperature when churning begins. It is impossible to give any one temperature as correct for churning under these conditions. Experience has shown that the best rule to follow is to regulate the temperature to a point at which the churning may be completed within 30 to 40 minutes for sour cream, or 50 to 60 minutes for sweet cream. In the summer the temperature probably will be between 45 and 55°F. (7.2 to 12.8°C.) and in winter from 55 to 70°F. (12.8 to 21.1°C.).

The churning should be continued until the butter granules are the size of peas. The buttermilk then is drawn from the churn. The use of a fine strainer is almost necessary; otherwise, some particles of butter will be lost in the buttermilk. A small quantity of cold water then is poured over the butter granules and when the water comes from the churn nearly clear, the buttermilk opening is closed. Next, cold water to an amount approximately equal to the amount of cream churned is poured into the churn, the top put on, and the churn revolved a few times. If the butter appears soft, the water which is used may be considerably colder than the churning temperature. The butter should be firm and waxy when worked and, to obtain this condition, it may be desirable to allow the butter to remain for some time in the cold water.

Many types of churns are used on farms, but the most common, and the most satisfactory, is the ordinary barrel churn.

Various forms of workers are used. In earlier years, the common practice was to use a wooden bowl into which the butter was placed. The working was done with a wooden ladle. Later, different types of small workers came into use, especially where considerable butter was made. The lever-type hand worker is as satisfactory as any. Any wooden utensil with which butter comes in contact, including churns, ladles, printers, or workers, should be washed thoroughly with hot water and afterward rinsed with an abundance of cold water.

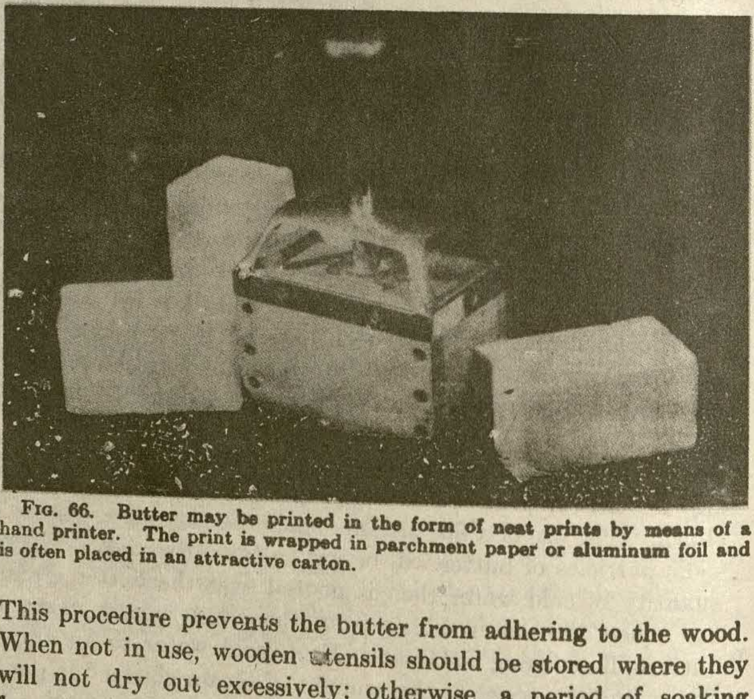


FIG. 66. Butter may be printed in the form of neat prints by means of a hand printer. The print is wrapped in parchment paper or aluminum foil and is often placed in an attractive carton.

This procedure prevents the butter from adhering to the wood. When not in use, wooden utensils should be stored where they will not dry out excessively; otherwise, a period of soaking for some hours will be necessary to fill the pores of the wood thoroughly before using. The amount of salt to be used is estimated from the weight of churned butter The usual amount is from ¾ to 1 ounce per pound of butter. The salt is sprinkled over the butter spread on the worker. By means of the lever or ladle, the working is continued until the butter is in a compact mass and the salt distributed uniformly. The proper stage to stop working is judged best by pulling the butter apart by means of a ladle. The individual grains or granules still should be visible but will show a tendency to string out. If uneven color appears after the butter stands a few days, the working was insufficient.

Hand-printing devices are desirable to put the butter into packages for the market. Parchment paper should be used for wrapping the prints. Another common plan is to pack the butter in stone jars ranging in capacity from 1 to 5 pounds. Farm-made butter is used on the farm where it is made or it may be sold locally. Except when a special outlet is known it is not advisable to undertake to ship butter of this class to the large markets.

CHAPTER XI

THE MANUFACTURE OF DAIRY PRODUCTS (*Continued*)

CHEESE

It is not known who manufactured the first cheese. That it is one of the oldest products made from milk is indicated by the fact that cheese is mentioned in the earliest parts of the Bible (Job X: 10 and I. Samuel XVII: 18). According to Anderegg, the people of Greece used cheese from 1000 to 450 B.C., and the Romans from 775 to 750 B.C. Cheese was a common food in what is now Germany by 800 A.D. For several centuries, during the Dark Ages, the monks of the monasteries were the leaders in the art of cheese making and in teaching others its manufacture. By the year 1000 A.D., cheese had become an important article of trade in the cities of Europe.

The types of cheese made in the European countries differed in the various sections and, as time progressed, certain sections became more or less known for the production of special varieties of cheese. Thus, today, the common cheeses, for which France is known, are Camembert and Roquefort; Switzerland, Emmental, usually known as Swiss cheese; England, Cheddar and Stilton; Belgium, Limburger; Holland, Edam and Gouda; the Scandinavian countries, Primost and Gammelost; and Italy, Gorgonzola and Parmesan. A number of factors, such as climatic conditions, geographic location, etc., were responsible for the development of the various types of cheeses in different localities.

Development of Cheese Making in the United States. Originally, cheese was made on the farm. This was true of the European countries and America alike. The cheese made in America, in the colonial days, was of the same varieties with which the colonists were familiar in Europe. Certain sections of America became more or less well known for special varieties of cheese because of the settlement of these sections by Europeans from a given locality. Thus, Cheddar cheese became a well-known product in Herkimer County, N.Y., and Swiss cheese in Green County, Wis. Because of the nationality of the early settlers in these states cheese early became an important product.

It was in the period between 1860 and 1870 that the greatest change took place in the cheese industry in America, as it was during this period that a large number of cheese factories were established. Jesse Williams, of Oneida County, N.Y., established a cheese factory in 1851 which is credited with being the first plant actually operated under the factory system. The introduction of this system soon resulted in a reduction in the amount of cheese made on farms. It has been estimated that, by 1869, two-thirds of the cheese made in America was made in factories. Today, the amount of cheese manufactured on the farm is practically restricted to that for home consumption, in a few scattered sections.

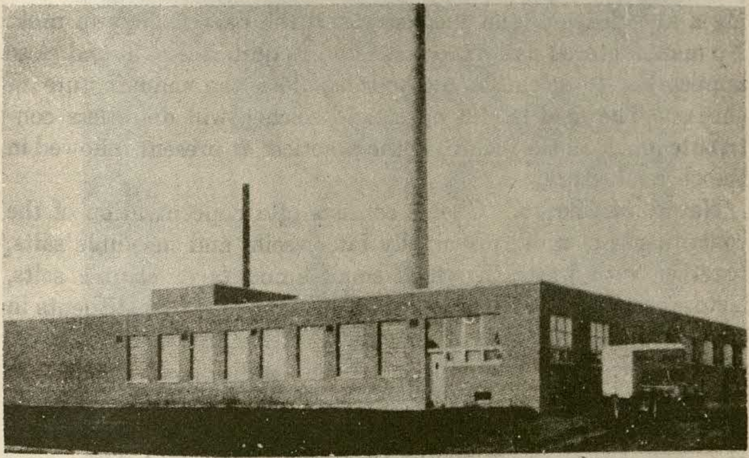


FIG. 67. A modern cheese factory. It is essential that fresh milk be secured in the manufacture of cheese. Large or small factories are placed in rural sections at points convenient to the milk producer. (*Courtesy of Land O'Lakes Creameries, Inc.*)

New York was the leading cheese-manufacturing state for a long period. Between 1899 and 1909, the demand for market milk in New York and the increased manufacture of cheese in Wisconsin resulted in New York's dropping to second or third place in the industry. Wisconsin is the chief cheese-manufacturing state at present, while the industry, in recent years, has been developing quite rapidly in Illinois, Indiana, Ohio, Missouri, Michigan, Minnesota, Oregon, and Texas.

Influence of Scientific Investigation. Comparatively little attention was given to the application of science to the manufacture of cheese before the establishment of the state experiment stations. Science found cheese a most interesting field, and science has done much to standardize the methods of manufacture of many different types of cheese. The process of manufacturing cheese under present-day conditions has turned, therefore, from rule-of-thumb methods, for which there were no explanations, to practices based upon the application of fundamental facts involving a knowledge of the chemistry and the bacteriology of milk. No manufactured dairy product requires quite the skill and close application to scientific methods as does the manufacture of cheese. The field is still open, and science will doubtless contribute much, in the future, to the practices at present followed in the cheese factory.

Nature of Cheese. Cheese consists of a concentration of the constituents of milk, principally fat, casein, and insoluble salts, together with water in which small amounts of soluble salts, lactose, and albumin are found. To retain these constituents in concentrated form, milk is coagulated either by means of lactic acid produced by bacteria or by the addition of rennet. A portion of water is removed by cooking, stirring, or draining the curd or by mechanical application of pressure. The cheese may or may not be ripened, but if ripened, the nature of the process depends upon the particular variety of cheese. The cheeses of particular interest to American markets are the American Cheddar, Colby, Cottage, Neufchatel, Roquefort, Swiss, Limburger, Liederkranz, Camembert, Brick, and Process cheese. Of this group Cottage, Cheddar, and Process or Loaf cheeses are the most common on the market.

Classification of Cheese. There are probably about eighteen distinct varieties of cheese. More than 400 names are applied to these varieties, however, owing to the fact that many cheeses, essentially of the same variety, were named in different localities. In addition, private concerns have found it profitable to mix cheeses of different varieties and sell the product in various types of packages under certain trade names. It is possible, however, to classify the cheeses according to two general types, namely, hard and soft.

Among the hard cheeses may be included those which are only semihard and ripened by certain molds. Roquefort and Gorgonzola are representatives of this group. In addition, there are several semihard cheeses, such as Brick, which are ripened by bacteria. Of the hard cheeses, there are a number that may be classed as very hard, with and without gas holes. Those without gas holes are such cheeses as American Cheddar and Edam,

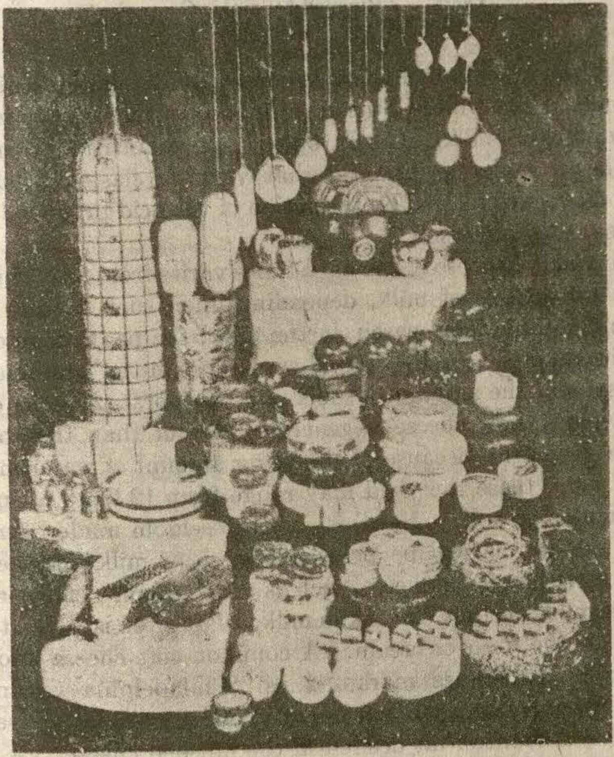


FIG. 68. Varieties of cheese. There are many varieties of cheese, prepared in different shapes and sizes. They may be coated with wax, paraffin, metal foil, plastics, rubber products, parchment paper, etc. The cheeses shown are common to Europe and the United States. (*Courtesy of Look Magazine, "Little Shop of Many Cheeses," March* 16, 1948.)

while the Swiss or Emmental cheese is representative of the very hard cheese possessing gas holes. Soft cheeses consist of the unripened acid curd, such as the ordinary Cottage cheese; Camembert, ripened by mold, and Limburger, ripened by bacteria.

CLASSIFICATION OF CHEESE

- Cheese
  - Hard
    - Very hard
      - Without gas holes, *Cheddar*
      - With gas holes, *Swiss*
    - Semihard
      - Ripened by molds, *Roquefort*
      - Ripened by bacteria, *Brick*
  - Soft
    - Ripened by bacteria, *Limburger*
    - Ripened by mold, *Camembert*
    - Unripened cheese, *Cottage*

With the exception of Cottage cheese, all the varieties of cheese common in the United States are made by the use of rennet to coagulate the milk. In Europe, large quantities of ripened soft cheeses and a few varieties that would be classed as hard, are made from curd formed by the action of the acid produced by the milk-souring organisms.

The yield of cheese of the hard types varies from 8 to 14 pounds from 100 pounds of milk, depending upon such factors as the percentage of fat and casein in the milk; the percentage of milk constituents, principally fat and casein lost in the manufacturing process; and the amount of moisture incorporated in the cheese. The yield of soft cheese is generally greater than that of hard cheese, primarily because of the larger amount of water incorporated. For these the yield may range from 12 to 16 pounds per 100 pounds of milk. Hard cheeses are seldom made from skim milk; though, as will be pointed out, skim milk may be used. Some varieties of soft cheese, such as the common Cottage cheese, may be made entirely from skim milk. Fat often is added to such cheese in the form of cream. A common soft cheese known as "Cream," sometimes marketed as "Philadelphia Cream," is made from cream with varying percentages of fat, depending upon the amount of fat desired in the finished cheese.

The hard cheeses in the United States, generally, are made from fresh raw or pasteurized milk. In countries such as New Zealand most of the cheese is made from pasteurized milk. There are distinct advantages to be gained from the pasteurization of milk for cheese making and a superior quality of cheese is usually obtained. With newer methods of pasteurization being introduced, and with larger factory units, its use has become more widespread in this country. There are some difficulties encountered with the coagulation of pasteurized milk, with the control of moisture content, and ripening, but these can be readily overcome. Milk is often pasteurized before making it into some of the soft types of cheese, such as Cottage.

Composition of Cheese. The composition of cheese depends upon the variety. All cheese contains the same constituents of milk, but in varying proportions. The most variable constituents are fat and water. The table shown on this page gives the approximate composition of some of the most common cheeses.

A number of factors influence the composition of a given cheese. The analyses submitted are averages reported by various workers and, doubtless, can be depended upon to represent typical cheese of the varieties included.

Milk for Cheese Making. Cow's milk is used most frequently for the manufacture of cheese; however, several varieties are made from goat's, sheep's, or mare's milk. The quality of milk used for cheese making on a commercial scale is of prime importance. It must be of the very best if desired results are to be obtained. Since most cheese made must pass through a ripening period, the type of bacteria which predominate in the milk may play an important part in the development of the flavor of a given cheese. To ensure satisfactory results, milk to be used for cheese making must be fresh, clean, of low bacterial content, and possess a clean, desirable flavor. Any abnormalities in flavor or in odor are to be avoided. A dirty milk or a milk containing large numbers of bacteria which are found associated with unsanitary methods in the dairy cannot be used in the manufacture of a high-quality cheese. Milk having undergone extensive fermen-

COMPOSITION OF CHEESE[1]

Variety of cheese	Fat, per cent	Protein, per cent	Lactose and ash, per cent	Water, per cent
Cottage...........	0.40 to 1.90	12.70 to 21.00	0.20 to 1.10*	71.40 to 79.90
Neufchatel........	23.00 to 28.00	18.00 to 21.00	0.50 to 1.25	50.00 to 55.00
Swiss (American)..	30.00 to 34.00	26.00 to 30.00	3.00 to 5.00	30.00 to 34.00
Cheddar (green)...	30.00 to 36.79	20.80 to 26.11	3.12 to 7.02	32.69 to 43.89
Roquefort.........	31.50 to 33.53	19.14 to 23.06	5.18 to 6.81	37.49 to 40.10
Brick.............	28.34 to 33.77	20.03 to 23.29	1.68 to 4.20	39.61 to 45.26

* Salt-free.

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[1] "Fundamentals of Dairy Science," 2d ed., Reinhold Publishing Corp., New York Table by Wright, Research Laboratory, Bureau of Dairy Industry, Washington, D.C Copyrighted.

tation is practically useless. Furthermore, no treatment of milk can be depended upon to improve a low-quality milk for the manufacture of cheese.

As it will be noted, all of the cheeses mentioned depend in a large measure upon microörganisms for the development of their characteristic flavor, aroma, or appearance. The organisms may be the principal factors, but in nearly every case there is evidence that various enzymes may also take part in the curing process. In every instance, there must be an accurate control of conditions of curing so that particular types of organisms may be favored; otherwise, untoward results will appear.

Cheese making is a splendid example of applied microbiology. The activities of manufacture and curing are directed toward control of fermentations by the selection and the cultivation of specific microörganisms under the most favorable circumstances.

Curd Formation. A characteristic of all cheese making is the formation of a curd or the coagulation of the milk. Coagulation is brought about by means of the action of lactic acid produced by fermentation, by the action of rennet or pepsin, or by a combination of lactic acid and rennet. In either case, it is the casein of milk which is congealed to form the curd. Casein is coagulated readily by acids and by enzymes, such as rennet and pepsin. The chemical changes involved in the case of acid coagulation and enzyme coagulation are distinctly different. When milk is coagulated by lactic acid, the calcium of calcium caseinate probably unites with the lactic acid to form calcium lactate. The casein is set free and forms a firm "gel" or curd. This same change in milk is brought about by other acids. A simple laboratory experiment will illustrate the action of acids such as hydrochloric, sulfuric, or acetic acid. The change taking place in milk when coagulated by rennet is set forth by Van Slyke and Price as being due to the formation of calcium paracaseinate, as a result of the action of rennet on calcium caseinate.

The rate of rennet coagulation is influenced by several factors, such as the temperature and the acidity of the milk. In the case of the hard variety of cheese, sufficient rennet is added to the milk to bring about a complete coagulation in 15 to 20 minutes. After adding and mixing rennet to milk, the first signs of coagulation may be observed in 8 to 10 minutes. It will be observed that there is slight thickening of the milk, flocculent curd particles will become visible to the eye, and, finally, the casein will form a firm gel. When the coagulation is dependent upon the action of lactic acid produced by the bacterial fermentation of lactose, from 8 to 16 hours may be required before sufficient acid is produced to bring about coagulation.

THE MANUFACTURE OF HARD CHEESE

The common cheese on the American market is correctly known as the American Cheddar. The processes involved in the making of this cheese are given in some detail on account of the importance of this variety, and, further, because of the fact that the procedure followed in the manufacture of other hard cheeses is much the same.

American Cheddar Cheese. This typical cheese in the hands of the retailer may be sold under a variety of names such as "American," "cream," "New York," or "Wisconsin." Regardless of the name, the assumption is reasonably correct that the process followed in manufacture is essentially that known among cheese makers as the "Cheddar process." The variety of cheese known as the "Cheddar" originated many years ago and secured its name from the village of that name in Somersetshire, England.

The manufacture of this cheese consists of a number of processes, each of which is intended to assist in concentrating the constituents of the milk and eliminating the water. At the same time, conditions are maintained which are favorable for the development of a desirable flavor and a characteristic body and texture in the finished cheese. The terms used and the processes will be outlined briefly.

Equipment Required. A vat is used to hold the milk and this vat sits inside a second designed to hold water. By controlling the temperature of the water in the outer vat, the temperature of the milk is adjusted to the proper point. The vat should be rectangular in shape, flat-bottomed, sloping, however, toward the center and the outlet end where the whey is drawn off.

Curd Knives. A set of two curd knives is required with which to cut the curd. The knives consist of a series of blades or wires set in a frame. The blades or wires are set at equal distances apart, and, in one knife, the blades or wires are set vertically in the frame and in the other horizontally.

Curd Rake. A rake constructed of wood or stainless steel is necessary for the stirring of the curd.

The Curd Mill. The curd mill consists of a piece of apparatus equipped to cut slabs of milk curd into strips about ½ to 1 inch wide and 2 to 3 inches long. One type consists of a hollow cylindrical drum suspended on an axle which can be revolved by either hand or motor power. At regular intervals on the cylinder is a raised section leading toward the inside of the drum and in which are inserted a number of thin blades. A tin tray serves to aid in guiding the curd toward the blades.

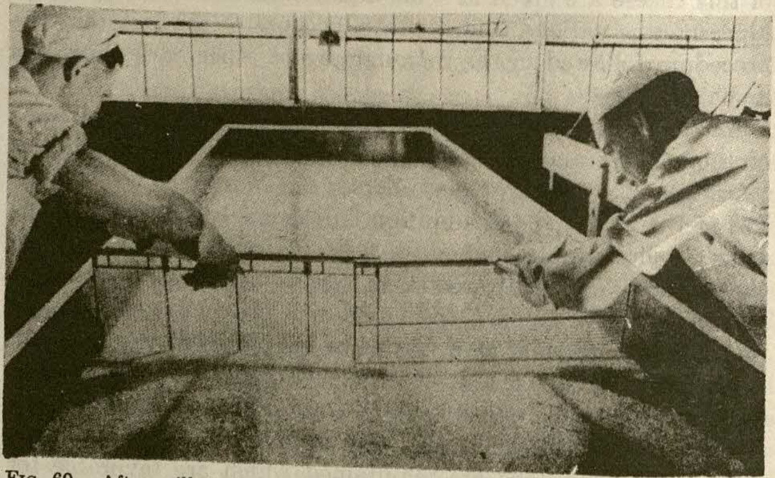

FIG. 69. After milk is clotted with rennet it is cut into small cubes by use of cheese-curd knives. (*Courtesy of Kraft Foods Company.*)

Cheese Hoops. Cheese hoops built of heavily tinned steel are used for holding the curd in preparation for pressing the curd and shaping the finished cheese.

Cheese Bandages and Circles. The cheese hoops are lined with a cheese bandage which is made of thin woven cotton known as cheesecloth. Into the bottom of the hoop is placed a heavy cloth circle on top of which is placed a thin starched cheesecloth circle. After the curd is placed in the hoop, still another thin starched cheesecloth circle is placed on top of the curd followed by a heavy cloth.

Cheese Press. A cheese press by means of which the cheese may be pressed after being placed in the cheese hoops is also required.

Paraffin Tank. A galvanized tank is required for paraffin. The tank must be equipped with a steam coil in the outer jacket in order that the paraffin may be heated. The cheese is dipped into the hot paraffin at the proper time.

Miscellaneous Equipment. In addition to the above equipment, the cheese factory will need considerable equipment such as a Babcock tester, milk-testing glassware, and apparatus for acidity testing. More modern factories find equipment for the complete analysis of milk and cheese desirable.

Other Supplies. Among the supplies needed, may be listed cheese rennet, cheese color, salt, paraffin, equipment for making the acidity test, sulfuric acid, etc.

Process of Manufacturing Cheddar Cheese. The milk intended for cheese making is placed in the cheese vat, as received at the factory. The practice is growing of standardizing the milk to a definite fat percentage in order to ensure cheese of a more uniform composition. A fat percentage of 3.25 per cent quite frequently is used. After standardizing, the acidity test is made to determine the percentage of acid in the milk. The common practice is to measure the acidity by titrating with tenth-normal sodium hydroxide, using phenolphthalein as an indicator.

Pasteurization of Milk for Cheese Making. The finest and most uniform quality of American Cheddar cheese may be made from pasteurized milk. The "holding" or the "flash" method of pasteurization may be used. A modified "flash" system is quite common. This consists of heating the milk to 163 to 165°F. (72.78 to 73.89°C.) and holding for 15 to 20 seconds. The milk is then cooled to the temperature at which rennet is to be added.

When milk is pasteurized for American cheese it is possible to standardize the method of manufacture. As a result the quality of the cheese is more uniform from day to day and a slightly higher yield is obtained.

Ripening the Milk. A culture of lactic-acid bacteria known as a "starter," and similar to butter starters, then is added to the milk. A small amount of starter, about 0.25 to 0.5 per cent, is usually added to the cold milk after it is placed in the cheese vat. The milk is then brought to the "setting temperature," 84 to 88°F. (28.9 to 31.1°C.) and allowed to "ripen" or to permit the lactic acid-forming organisms to grow and thus bring about an increase in the titratable acidity. Usually the titratable acidity is permitted to reach 0.17 to 0.2 per cent, which is the desired acidity at the time of adding rennet.

Addition of Cheese Color. While the milk is being brought to the setting temperature, cheese color may be added, the amount depending upon the shade desired. If a light-straw color is desired, about ⅓ ounce of cheese color may be added to each 1,000 pounds of milk. For a deep yellow, 2 ounces per 1,000 pounds of milk may be added. The milk is stirred thoroughly to ensure an even distribution of color.

Setting the Curd. The milk is brought to a temperature of 84 to 88°F. (28.9 to 31.1°C.) by heating the water in the outer vat. Casein, it will be recalled, is coagulated by rennet. After adding rennet extract, 2.5 to 4 ounces per 1,000 pounds of milk, the casein of the milk forms a firm curd. Sufficient rennet is added to bring about a firm coagulation within about 20 minutes. The amount needed is regulated by the results obtained from day to day. The rennet extract is diluted with water to about 20 times its volume and added slowly to the milk. Meanwhile, the milk is stirred thoroughly to ensure uniform distribution.

Cutting the Curd. After a firm curd is formed, it is cut with the cheese knives. The curd should be cut into small cubes about ¼ to ⅜ inch square. This is accomplished by cutting the curd lengthwise of the vat with the horizontal curd knife and both lengthwise and crosswise of the vat with the perpendicular curd knife.

Heating the Curd. After cutting, the curd is heated. This is accomplished by heating the water surrounding the vat with live steam or hot water. The temperature of the whey surrounding the curd is raised slowly to that of 98 to 104°F. (36.7 to 40.0°C.). The heating temperature should be reached in 30 to 40 minutes. The curd particles are kept from matting, and the whey agitated from time to time by stirring with the curd rake or mechanical stirrer. During the heating process, the curd particles contract to about one-half their original size, eliminating considerable water or whey. The cheese maker determines the point at which to stop heating by the feel and appearance of the curd particles and the increased acidity of the whey.

Removing the Whey. After the cooking is completed, the whey is removed from the curd by placing a screen strainer in front of the outlet of the vat to draw it off at this point. The curd remaining in the vat is then piled on each side of the vat to permit it to drain and mat.

Cheddaring the Curd. After removing the whey and piling, the curd is cheddared. It is this process which distinguishes Cheddar cheese from many others. In the cheddaring process the curd is piled at both sides of the vat and permitted to mat. The small curd particles soon adhere to one another forming a completely solid mass. By means of a large knife the matted curd is cut into strips which may be about 6 to 10 inches wide by 8 to 14 inches long and 2 to 4 inches thick. The curd strips are turned at intervals of about 15 minutes and piled two to

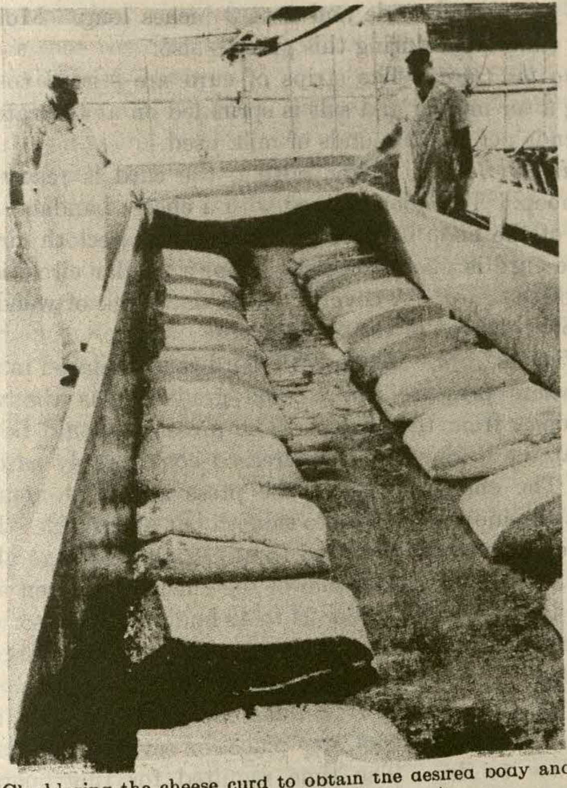

FIG. 70. Cheddaring the cheese curd to obtain the desired body and texture. (*Courtesy of Kraft Foods Company.*)

six slabs deep. When the cheddaring process is completed, the small particles lose their identity completely, fusing together into a practically solid mass of curd. Considerable water or whey is eliminated during the process.

Milling the Curd. After cheddaring, the curd is passed through the curd mill, which cuts the slabs of curd into strips about ½ to 1 inch wide and 2 to 3 inches long. Moisture or whey is eliminated during this process also.

Salting the Curd. The strips of curd are stirred to prevent matting after milling and salt is sprinkled on at the rate of 1 to 2½ pounds per 1,000 pounds of milk used.

Hooping the Curd. After salting, the curd is ready for the cheese hoop. The hoop is lined with a cheese bandage. In the bottom of the hoop is placed a starched cheesecloth circle and, after the curd is placed into the hoop, a similar circle is placed on top of the curd. A cover of a circular block of wood is then placed over the top of the curd.

Pressing the Curd. The hooped curd then is placed in a cheese press, where pressure is increased gradually as the whey or water comes from the cheese. The pressure should be applied gently at the beginning and increased considerably as the curd packs. The cheese is left in the press about 24 hours, after which it is removed in order to smooth out all wrinkles that may be formed on the bandage and to adjust the bandage along the rim at the top and the bottom of the cheese. It then is placed again in the press for another 24 to 48 hours. The intervals here recorded have been reduced very decidedly in most large American factories to save time and equipment.

Paraffining the Cheese. Cheddar cheese is removed from the press and placed in a cool, dry place for several days to permit the surface to dry. The time required for this operation is reduced in some plants to a few hours by placing high-speed fans in the drying rooms. After a dry surface is secured, the cheese is dipped into a vat of paraffin which has previously been heated to 212 to 240°F. (100–115.56°C.). This procedure covers the cheese with a thin layer of paraffin, closes all pores, kills any mold that may have been deposited upon the surface, and checks evaporation of the water from the cheese during curing.

Curing Cheddar Cheese. The curing of Cheddar cheese is brought about through a series of changes in the protein. The cheese is placed upon shelves in a well-ventilated room maintained at a temperature ranging from 40 to 65°F. (4.4 to 18.3°C.). The lower the curing temperature, the slower is the curing process and the better the quality of the finished cheese. The finished cheese contains sufficient moisture for bacterial growth. While the exact details of the ripening of Cheddar cheese from the bacteriological viewpoint are not completely understood, it appears that the *Streptococcus lactis* type of bacteria predominates in the fresh cheese and provides an acid medium which restricts the growth of most bacteria. These bacteria soon decrease in numbers, however, and are replaced by certain other types, such as *Lactobacillus casei*, which have persisted in the milk and which increase tremendously and attack the protein to produce a part of the characteristic flavor of Cheddar cheese. Thus it is, in part at least, a bacteriological process, although certain enzymes present in the milk and rennet, or produced by microörganisms, apparently play important roles. Whenever organisms other than those mentioned above gain an ascendancy, defects such as those termed "gassy," "burnt," "bitter," "putrid," "yeasty," or "fruity," may appear; the surface of the cheese may be marred by discolored areas, or mold may grow extensively, especially upon the surface.

Forms of Cheddar Cheese. Cheddar cheese appears on the market in a number of forms and sizes. The various shapes are secured by using hoops of different types. The typical cheese weighs about 40 to 50 pounds, is 13½ to 15 inches in diameter, and 10 to 12 inches high. Thom and Fisk present the following table showing the various sizes and shapes of Cheddar cheeses:

SIZE OF CHEDDAR-CHEESE HOOPS, WEIGHT, AND TERMS APPLIED TO CHEESE

Diameter of hoop, inches	Height of cheese, inches	Weight of cheese, pounds	Terms applied to cheese
6 to 7	7 to 8	9 to 11	Young America
Tapers, 5 to 7	10 to 14	10 to 16	Longhorn
12 to 14	3½ to 4½	18 to 24	Daisy or picnic
14 to 15½	4 to 6	30 to 40	Twin (two in same box)
14 to 16	4 to 7	35 to 40	Flat
13½ to 15	10 to 12	40 to 50	Cheddar
14 to 16	12 to 15	75 to 90	Export

The most common of these cheeses in the retail store is the Twin. The Cheddar is used primarily in the making of Process or Loaf cheese and cheese foods. In addition to the above, rectangular cheeses of the same type are on the market.

Whole-milk or Skim-milk Cheddar. Cheddar cheese may be made from whole milk, skim milk, or from milk from which part of the cream has been removed. A Cheddar cheese is never made from cream. The term "cream cheese" applied to Cheddar cheese in some localities refers to typical Cheddar cheese made of whole milk. Cottage cheese made of skim milk is often called "creamed Cottage" when cream is added.

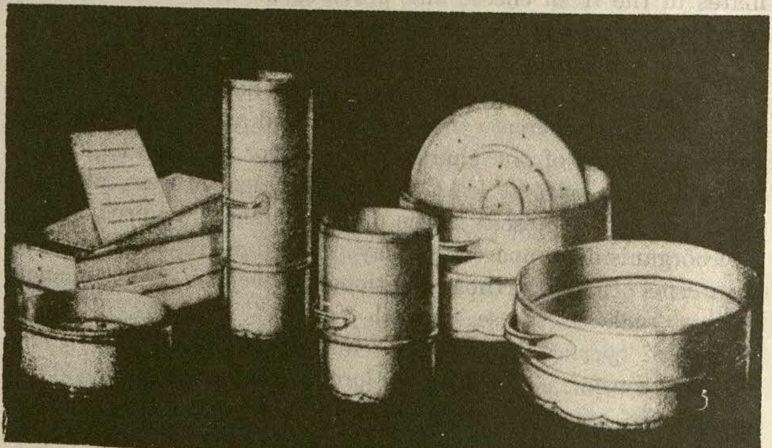

FIG. 71. A group of cheese hoops. Cheese of the Cheddar type is shaped into various forms by placing the curd into differently shaped hoops such as illustrated. Here is shown a Loaf cheese mold in the background at the reader's left. In the left foreground is shown a form commonly used in making cheese known as the Gouda; following, there are shown the hoops used in molding the Longhorn, Young America, Export Cheddar, and Twin Cheddar cheeses. (*Courtesy of Creamery Package Manufacturing Company.*)

Cheddar cheese made from skim milk must be labeled "skimmed Cheddar" in most states. These same states require cheese to be labeled "half skim" or "three-quarters skim" if Cheddar cheese is made with these proportions of skim and whole milk.

Market Grades of Cheddar Cheese. The market grades for American Cheddar cheese are not so well recognized as those for butter. State and federal government agencies have attempted to set up specifications for cheese grades somewhat at variance with commercial practice, with the result that considerable confusion exists on national markets. Cheese is sold on the market according to the style such as Daisies, Longhorns, Twins, etc. Not only is Cheddar cheese sold in various styles, shapes, and sizes, but the age of cheese is a factor determining its value on the market. The term "fresh or current" in market channels refers to a Cheddar cheese that has been made not more than a few days to a week or two previous to marketing. The term "medium cured" is used in market channels to designate a cheese that has been held 1 to 3 months, while the term "aged" or "cured" indicates a cheese that has been held for sufficient time to develop a definite "Cheddar" flavor. The term "grass cheese" is applied to Cheddar cheese made during that season when cows have access to lush, green pastures. If such cheese is further identified by the year it was made, the buyer may be able to judge the age of the cheese. A well-aged Cheddar cheese is sold at a premium on the market.

The facts set forth above serve to indicate the complications that arise in formulating market grades for Cheddar cheese. The grades of American Cheddar cheese proposed by the U.S. Department of Agriculture are outlined in the Appendix.

The channels through which cheese is sold are similar to those for butter. Dealers in cheese maintain large warehouses in which cheese is stored and from which it is distributed to smaller wholesale and retail dealers. If Cheddar cheese is to be held for a long period, it is generally kept in cold storage at a temperature around 40 to 50°F. (4.4 to 10.0°C.).

The marketing of other types of cheese is much the same as Cheddar with the exception of the soft cheeses such as Cottage and Cream. These are sold more often by the manufacturer directly to the retail distributor or the consumer.

Defects in Cheddar Cheese. The defects in common cheese are those of flavor, body and texture, color, and outside appearances. The score card used in educational scoring contests for cheese is as follows:

Flavor	45
Body and texture	30
Finish	15
Color	10

It must be remembered that the score card is not so commonly used in the grading of cheese as in the grading of butter.

Flavor Defects. The judge of cheese is accustomed to the use of certain terms in describing the flavor defects in cheese which are more or less understood by all acquainted with the industry. Such terms as "high acid," "sour," "bitter," and "unclean" are in use and the particular defects to which they are applied are recognized. The flavor of cheese generally is judged, by the expert, not by the taste but by the smell. A small plug of the cheese is removed and kneaded in the hand and the odor of the warm cheese noted. A desirable cheese flavor is exceedingly difficult to describe in words. It may be described best as a clean, pleasant, rich, nutty flavor.

Body and Texture Defects. Cheddar cheese should have a firm, waxy, smooth, compact body and texture. One of the most common defects is termed "gassy," in which case, small gas holes appear throughout the cheese. Such a condition is not desirable, but it occurs so frequently that the average consumer may be led to believe this condition characteristic of Cheddar cheese. Gas holes actually indicate unsatisfactory conditions in the handling and care of the milk or the improper use of starter in the manufacture of the cheese. Such cheeses often have a decidedly unpleasant flavor. In addition to gas holes, the body may be too pasty, or too firm, or too rubbery. If the curd particles have failed to fuse during pressing, the cheese body may be loose. A cheese high in water may be pasty, while one very low in water may be hard and dry.

Color Defects. Color in Cheddar cheese may be too high or too light, streaked or uneven; white specks may be visible, or it may be marbled or mottled. It sometimes occurs that the fat is squeezed from cheese during pressing, so that a thin layer is formed between each individual curd particle. Thus, the color is darker around the curd particle. The cheese judge uses the term "seamy" in this case. Certain bacteria, yeasts, or molds may also produce distinct discolorations. A desirable color is one that is uniform throughout.

Defects in Finish. The appearance of cheese is of considerable importance. The bandages must be smooth and the cheese well shaped. Wrinkles in the bandage, uneven edges, and unclean surfaces are objectionable.

Emmental or Swiss Cheese. Emmental or Swiss cheese originated in Canton Bern, Emmental, Switzerland. It is a cheese of the hard type, has a mild, somewhat sweetish taste, and is particularly characterized by the holes or eyes which develop in the cheese. These should be about ½ to ⅝ inch in diameter and from 1 to 3 inches apart.

The cheese is made by cooking milk in huge copper kettles. The modern procedure, in American factories, is to inoculate the milk with pure cultures of lactobacilli and *Streptococcus thermophilus*, which produce lactic acid, assist in checking the development of undesirable fermentations, and aid in controlling the ripening of the cheese; and with pure cultures of *Propionibacterium shermanii*, to aid in the development of the eyes or holes and the sweetish flavor. The milk is coagulated with rennet and the curd cut in a manner somewhat similar to the process used in the case of Cheddar cheese. In the case of Swiss cheese, however, the curd is cut a second time, before heating or cooking proceeds, by giving the curd a circular motion in the vat and by using a specially constructed instrument called the "harp" and a fixture within the kettle known as the "breaker." The curd thus is broken into pieces about the size of wheat kernels. The curd is cooked until sufficiently firm. The curd then is brought into a cone-shaped pile in the kettle by giving it a rotary motion while in the whey. The mass of curd then is removed from the whey by means of a cloth resembling burlap. The curd then is placed in hoops which are about 4 to 6 inches deep and of varying diameters. After pressing for about 24 hours, the cheeses are covered with a layer of salt and turned occasionally. After about 2 days, the cheeses are placed in a tank of salt brine where they remain for from 1 to 4 days. The cheese is then cured from 3 to 6 months. The bacterial fermentations which take place are very delicately adjusted to one another and they demand careful attention on the part of the cheese maker to see that conditions are favorable for the proper sequence of these fermentations.

If this is not done, defects may appear. The cheese may be "blind," due to the fact that the propionic acid bacteria have not grown properly. Other defects may appear because of the activity of other bacteria which have not been held in check. Bacteria may be responsible for (1) the "stinker" Swiss cheese, (2) "blowing" where the cheese is puffed out abnormally due to gas, and (3) the "Niszler" defects due to gas-producing spore-bearing bacteria.

Roquefort Cheese. The manufacture of Roquefort cheese has been carried on in the southern part of France for at least six centuries. The village of Roquefort, France, from which the cheese derives its name, has been famous for Roquefort cheese for many generations. The cheese is characterized by its striking marbled or mottled appearance, due to the growth throughout the cheese of the bluish-green mold, *Penicillium roqueforti*. In France, the cheese is made primarily from sheep's milk. American manufacturers have been successful in making a Roquefort type of cheese from cow's milk which lacks some of the strong flavor of the cheese made from sheep's or goats' milk but is equal to or better than the imported variety in most respects. It is sold on the market usually as "Blue" cheese.

The milk for American Blue (Roquefort) cheese should be clean and fresh and should contain from 3.8 to 4 per cent of milk fat. Starter is added to the extent of 3 to 4 per cent. The milk is allowed to develop from 0.20 to 0.23 per cent of acidity. It is then set at 85 to 86°F. (29.44 to 30.00°C.). Coagulation is brought about by the addition of rennet, using from 3 to 4 ounces per 1,000 pounds of milk. After allowing the milk to stand from 1 to 1½ hours, the curd is cut with curd knives into cubes from ¾ to 1 inch square. A few minutes after cutting, the curd is removed from the whey to a draining rack, where it is permitted to drain for 15 to 20 minutes. The curd is then placed in forms that are 6 inches high and 7⅜ inches in diameter. The forms are perforated with small holes 3/32 inch in diameter and 3/16 inch from center to center. As the curd is placed in the forms it is sprinkled with spores of *Penicillium roqueforti* previously grown on bread and dried. After placing the curd in the forms it is permitted to drain for 24 hours in a room held at 68 to 72°F. (20.00 to 22.22°C.) and at a relative humidity of 85 to 90 per cent. The forms are turned at frequent intervals during the first day. At the end of 24 hours the cheese is removed from the forms, placed on draining boards, and turned twice daily. At the end of 3 to 5 days the cheese is placed in a room at 48 to 50°F. (8.89 to 10.00°C.) and salted.

Salting is accomplished by rubbing salt on the cheese at the rate of 7.5 pounds to each 100 pounds of green cheese. At least three applications of salt are required. After salting, the cheese is pierced with needles. This permits free access of air to the interior of the cheese.

The cheese is held in a room at 48 to 50°F. (8.89 to 10.00°C.) and at a relative humidity of 95 per cent for about 3 months. At the University of Minnesota Experiment Station, large sandstone caves are used for holding cheese during this period. Adjacent and similar caves are also being used by several commercial concerns. At the end of this period the cheese is wrapped in tinfoil and placed at 40 to 45°F. (4.44 to 7.22°C.) until the characteristic flavor develops, which requires 3 to 6 months. The ripened cheese is mottled with a blue-green mold, which is especially luxuriant along the lines of the punctures made in the cheese. The flavor and aroma of the cheese are due partly to caproic, capric, and caprylic acids, or compounds formed from them, which are liberated from the milk fat in the cheese by the action of mold enzymes. Other compounds which may arise from protein decomposition also may play a part in flavor production.

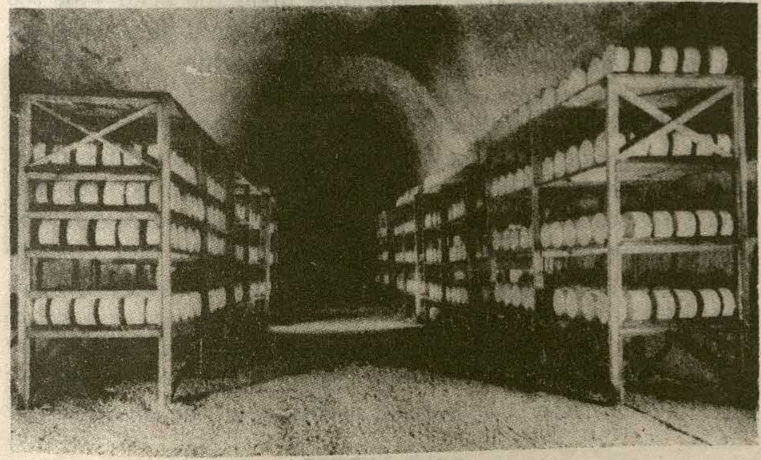

FIG. 72. A type of cheese, resembling Roquefort, is ripened in sandstone caves that occur along the banks of the Mississippi River at St. Paul, Minnesota, by the Dairy Division of the University of Minnesota. This variety of cheese is being made to a limited extent in Minnesota, Wisconsin, Iowa, and California.

Brick Cheese. Brick cheese was originated in America. It probably got its name from its shape or because bricks are commonly used for weighting down the press during the process of pressing. The cheese resembles Swiss cheese in that it has a slight sweetish taste; however, the flavor is strong as compared with Swiss, resembling, to a certain degree, the flavor of Limburger cheese. The body of the cheese is rather elastic and often contains numerous small round holes or eyes.

The cheese is made from whole milk to which 0.10 to 0.25 per cent of starter is added. The milk is set at about 90°F. (32.22°C.) and rennet added at the rate of 2½ to 3½ ounces per 1,000 pounds of milk. The curd is cut with cheese knives, as in the making of Cheddar cheese. It is then slowly cooked to 106 to 115°F., (41.11 to 46.11°C.) depending upon the acidity of the original milk. After cooking, the curd is placed in a rectangular box without a bottom and along the insides of which are perpendicular grooves which permit drainage. The cheese is pressed by covering with a wooden follower and placing bricks on the cheese for pressure. After remaining in the molds for about 24 hours, the cheese is removed and the surface rubbed with salt. Salt is applied in this manner for about 3 days in succession, the cheese being piled about three deep during this period. The cheeses are then ripened at a temperature of 60 to 65°F. (15.6 to 18.3°C.) for about 60 days.

The curing room should be maintained at a relative humidity of nearly 90 per cent. The ripening is brought about largely by the action of bacteria upon the constituents of the cheese.

SOFT CHEESE

Limburger Cheese. Limburger cheese originated in Belgium, and was first marketed in the town of Limburg. A cheese of the same type is made in Germany and is known there under the name of "Backstein." Large quantities now are made in the states of New York and Wisconsin. The cheese possesses a characteristic strong odor and taste, weighs about 2 pounds, and is marketed in packages about 6 by 6 by 3 inches.

The best Limburger cheese is made from whole milk; however, some manufacturers make the cheese from skimmed milk or milk from which a part of the milk fat has been removed. The curd is set with sufficient rennet to bring about coagulation in about 40 minutes. A temperature of nearly 96°F. (35.6°C.) is used and no further heat is applied. After cutting, the curd is dipped into rectangular forms 28 inches long, 5½ inches broad, and 8 inches deep. After being allowed to drain, the cheese is removed from the forms and salt rubbed daily over the surface until the cheese becomes slippery. The cheese is then placed in curing rooms held at a temperature of about 60°F. (15.6°C.). It requires about 2 months for the cheese to ripen.

The Limburger cheese is made from the highest quality of fresh milk. No starters are used. The ripening of this cheese takes place due to the activity of a number of proteolytic types of bacteria and enzymes, naturally present in the milk, which work together under the conditions of storage and salting employed in its manufacture.

Camembert Cheese. Camembert cheese originated in the northern part of France. The cheese is about 4½ inches in diameter and about 1 inch thick. It is wrapped in tinfoil and placed in a small wooden box the same shape as the cheese. The cheese generally is covered with a rind consisting of dried cheese and mold. Its interior is soft, yellowish in color, creamy or almost fluid, depending upon the degree to which it is ripened. The flavor is somewhat similar to Limburger but not so strong.

Milk for Camembert cheese is set at 78 to 87°F. (25.6 to 30.6°C.) and sufficient rennet added to bring about a firm coagulation in from 2 to 5 hours. The curd is then placed in perforated tin forms or hoops which are set on rush mats, where the cheese is allowed to drain. After about 18 hours the cheese is turned frequently for about 2 days. The cheese is then removed from the form and salted on the outside. The curing of Camembert cheese is very difficult. The curing rooms must be maintained at a temperature between 53 and 59°F. (11.7 to 15.0°C.) and at relatively high humidity.

In this country a regular *Streptococcus lactis* culture is used to provide the acidity to control fermentation. To obtain the characteristics of Camembert, a mold culture is added, sometimes to the milk, and sometimes sprinkled on the curd or with the salt. In this case, however, the mold is the *Penicillium camemberti*, which differs somewhat from the Roquefort mold. The cheese is placed in the curing rooms, which are kept at the proper temperature and with a high humidity. The curd gradually dries and the growth of the Camembert mold is held in check as it is not desirable to obtain a too rapid, vigorous, or luxuriant growth of the mold or of the various bacteria also developing within the cheese. A slime made up of the mold and some bacteria develops on the surface of the cheese. The mycelium from this mass of mold penetrates into the cheese. Enzymes from the mycelium attack the curd and break it down, starting from the outside and proceeding toward the center. Eventually, the characteristic appearance and flavor of Camembert are developed. From 15 to 20 days are required to bring about the desired changes in the casein. The cheese then is cured at a lower temperature and humidity for about 6 weeks, when it is ready for the market.

Cottage Cheese. The principal unripened soft cheese made in America is the common Cottage cheese. This type of cheese is generally made of skim milk. The milk for best results should be pasteurized. It is set at a temperature of 68 to 72°F. (20 to 22.2°C.) and approximately 5 per cent of good starter is added. After 8 to 12 hours the milk will coagulate and form a firm curd. The curd may be cut with curd knives as in the case of Cheddar cheese, after which it is cooked slowly to 98 to 110°F. (36.7 to 43.3°C.). The whey then is removed and the curd allowed to drain. In some factories the curd and whey are drawn into cheesecloth bags, which are hung in a cool room where the whey is permitted to drain. If a starter flavor is not desired, the curd may be washed with cold water. The curd then is stirred and salted to taste. The quality of such cheese is greatly improved by the addition of cream in sufficient quantity to raise the fat content of the finished cheese to about 5 to 10 per cent. A yield of from 12 to 16 pounds per 100 pounds of milk can be secured in making Cottage cheese, depending on the amount of moisture the cheese contains. This cheese possesses rather poor keeping quality because of its high moisture content and the possibility that the undesirable types of microörganisms may gain an ascendancy and cause the rapid decomposition of the product with the accompanying disagreeable flavor and aroma. The keeping quality of the cheese is improved, however, by pasteurizing the milk previous to setting.

Cream Cheese. A cheese common on American markets is known as "Cream cheese" and sometimes under a trade name such as "Philadelphia Cream" cheese. This cheese has a mild, rich flavor and is used primarily as a base for attractive salads or as a spread for bread.

Cream cheese, as the name implies, is made from cream of varying percentages of fat, with or without the addition of milk or skim milk or both. The cream is pasteurized and usually homogenized. A starter is added to the cream and usually rennet. The mixture is then held until coagulated, after which it is placed in cloth bags and allowed to drain. About 3 to 4 days are required for the cheese to drain. It is then salted, worked into a paste by mixing machines, and placed into packages of the desired size and shape. There are a number of modifications of this simple method and other ingredients may be added for a variety of purposes.

Process Cheese—Cheese Spreads. Process, pasteurized, or Loaf cheese is reworked cheese made from one or more varieties, or cheese of the same variety but of varying stages of ripeness. For example, a very common loaf cheese on the market consists of a mixture of old and green Cheddar cheese. The cheeses are cut into small pieces, usually run through grinders, then placed in vats, pasteurized, and homogenized. The liquid cheese mixture which results is permitted to flow into forms of the shape desired and allowed to cool. The process also may consist simply of grinding Cheddar cheese of varying degrees of ripeness into a paste with butter or other cheeses such as Neufchatel, Roquefort, Swiss, etc., depending on the flavor desired. Such cheese is often referred to as "Club cheese." So many combinations may be had, however, by mixing various cheeses, with or without the addition of cream, and by including many different materials for seasoning that the possible number of different cheeses becomes almost unlimited. In a general classification, however, it is best simply to refer to the group as Processed, Reworked, or, as often termed on the market, Loaf Cheese, or Cheese Spreads.

Cheese Food. "Cheese food" was a product of the Second World War. It was introduced primarily to avoid emergency regulations imposed on the cheese industry when the United States government set up a system of food rationing. It is a process cheese to which additional water and milk solids-not-fat are added. It is now defined by federal regulations.

NOTE: The reader may refer to *The Federal Register*, Vol. 14, No. 17, April 22, 1949, for federal rulings, definitions, and standards of various types and varieties of cheese.

CHAPTER XII

THE MANUFACTURE OF DAIRY PRODUCTS (*Continued*)

ICE CREAM

When ice cream was first made is not known. No reference is made to it in the literature of the ancients or in the Bible. According to several writers, water ices were introduced to Europe from Italy. From water ices probably developed recipes for frozen desserts which contained milk or cream. Mention is made in French and English cookbooks, published between 1769 and 1776, of "butter ices or cream ices." The term, "ice cream," is found in an advertisement which appeared in the *New York Gazette* of May 19, 1777, by Philip Lenzi, who termed himself a "Confectioner from London," which reads as follows: "May be had almost every day, ice cream; likewise, ice for refreshing wines, etc." The director of the Louisiana State Museum reported in 1945 finding an advertisement in a paper dated April 20, 1808, reading, "Ice cream may be had at the Coffee House everyday between the hours of 12 and 9 o'clock."

The manufacture of butter and cheese developed in the home but ice cream and ices apparently were products of the exclusive café and caterer. The method of making was long a guarded secret. The idea of manufacturing ice cream commercially and selling it wholesale was introduced by an American, Fussell, of Baltimore in 1851. Fussell later established factories in Washington, D.C., Boston, and New York. Commercial ice cream is now manufactured in all the principal cities of America and in many of the cities abroad.

Though ice cream is made in the home, the amount so made has always been very small as compared with the quantities sold from the factory. Therefore, attention will be directed in the discussion to follow, primarily, to the manufacture of commercial ice cream.

Ice Cream Defined. Ice cream is a product which may contain a variety of ingredients in addition to milk, cream, and sugar.

In 1906, the U.S. Department of Agriculture defined ice cream as follows: "Ice cream is a frozen product made from cream and sugar, with or without a natural flavoring and containing not less than 14 per cent of milk fat. Fruit and nut ice cream must contain not less than 12 per cent of milk fat." Legal definitions for ice cream are far more inclusive today. They are worded to make it clear that ice cream is a frozen dairy product, made from a combination of milk products together with one or more of other ingredients, such as eggs, sugar, and honey, with or without flavoring and coloring, and with or without edible gelatin or

FIG. 73. A modern ice-cream plant. Commercial ice cream is manufactured in such a plant and distributed to small retailers over a town or city. A plant of this size may manufacture from 300,000 to 500,000 gallons of ice cream yearly. (*Courtesy of Ives Ice Cream Company.*)

vegetable stabilizer. The definition frequently makes a point of the fact that freezing has been accompanied by agitation of the ingredients. Modern definitions not only specify the per cent of milk fat that must be contained in ice cream, but specifically mention the per cent of milk solids-not-fat, fruits, nuts, cocoa or chocolate, or confections included. Further, they may specify the per cent of food solids that must be contained in a given volume of ice cream. A typical definition embodying the abovementioned specifications, and as adopted by the Minnesota State Legislature of 1949, is set forth below.

> Ice cream means the clean, pure, frozen product made from a combination of milk products and one or more of the following ingredients: eggs, sugar, dextrose, corn syrup, in liquid or dry form, and honey, with or without flavoring and coloring, and with or without edible gelatin or vegetable stabilizer; and in the manufacture of which freezing has been accomplished by agitation of the ingredients. It contains not more than .5 per cent by weight of edible gelatin or vegetable stabilizer, not less than 12 per cent by weight of milk fat, and not less than 20 per cent by weight of total milk solids, except when fruits, nuts, cocoa or chocolate, maple syrup, cakes or confections are used for the purpose of flavoring, then it shall contain not less than 12 per cent by weight of milk fat and not less than 20 per cent by weight of total milk solids, except for such reduction in milk fat and in total milk solids as is due to the addition of such flavoring, but in no case shall it contain less than 10 per cent by weight of milk fat or less than 16 per cent by weight of total milk solids. In no case shall any ice cream contain less than 1.6 pounds of total food solids per gallon or weight less than 4½ pounds per gallon.

The state laws in America governing the milk-fat content of ice cream vary in the requirement from 8 to 14 per cent for plain ice cream. For ice creams containing fruit, nuts, or chocolate, the milk-fat content varies from 8 to 12 per cent. A majority of the states have set up minimum milk-solids requirements as well as regulations governing the weight of a gallon of ice cream.

Classification of Ice Creams and Related Frozen Foods. The classification here suggested is intended to include those frozen foods commonly prepared in commercial ice-cream factories. Ice cream and frozen dairy foods are prepared in a variety of ways as to composition, flavor, and color, as well as the shape and form. A simplified classification of these is set forth below.

A. Ice Cream
  1. *Standard Ice Cream.* A standard base mix is one from which a standard ice cream of any flavor may be prepared. The composition of this standard mix is generally made to conform with the law of the state in which it is intended to sell the finished ice cream. There are two general types of standard ice cream.
    a. Standard Ice Cream of Various Flavors. Vanilla, chocolate, fruits, candies, and nuts, etc., may be used to flavor ice cream. The flavoring materials, fruits, nuts, etc., are uniformly distributed in the finished ice cream.
    b. Variegated or Ripple Ice Cream. This is generally a vanilla ice cream into which flavored syrups and fruit or nut preparations are mechanically injected to produce a variegated or marbleized effect. Recently a device has been patented for blending ice creams of different colors or flavors to produce this marbleized effect.
  2. *Special Ice Creams.* There are a large variety of ice creams that fall into a class that may be termed "special ice cream." They differ from "standard ice cream" in that they may be high in milk fat, high in color, in eggs, or in some fruits. Typical of the ice creams that may be grouped in this classification are:
    a. Custard, a highly colored ice cream, which may or may not be above the milk-fat content of standard ice cream and usually contains a liberal portion of whole eggs.
    b. Parfait is an ice cream high in milk fat, containing eggs and a liberal amount of fruit or nuts or a combination of each.
    c. Bisque ice cream is usually rich in milk fat and flavored with macaroons, grape nuts, or cake.
    d. Mousse is frozen whipped cream, usually highly flavored.
    e. Philadelphia or New York ice cream (common in some sections of America) is generally highly colored to a golden-yellow; it may or may not be above the milk-fat content of standard ice cream and contain eggs.

B. *Ice Milk.* This is a frozen product made from a combination of milk products, sugar, and one or more other ingredients similar to those commonly used in the manufacture of ice cream. It is made to contain a milk-fat content higher than is specified by law for sherbets and lower than that required for ice cream. Usually the milk-fat content is between 2 and 6 per cent. It is generally served from the freezer in a soft state. When approximately 3 per cent malted milk is added and chocolate added for flavoring, ice milk is sold as "frosted chocolate malted milk."

C. *Milk Sherbet.* Sherbets are prepared from milk to which is added sugar and fruits or fruit juices. The milk-fat content of milk sherbets usually does not exceed 2 per cent. So that it may be distinctly different from ice milk, a few states require that it contain not less than 0.4 per cent acid.

D. Fruit Ice. A fruit ice is similar to sherbet but contains no milk or milk products.

E. Novelties. Individual forms of frozen products such as are shown in Figs. 77 and 78 may be made from ice cream, fruit ice, sherbet, or whipped cream or a combination of two or more of these frozen products. A few of the popular novelties are chocolate-coated ice-cream bars and such trade-marked novelties as "Eskimo Pie," "Popsicle," "Drumstick," and "Cheerio."

Composition of Commercial Ice Cream. It is impossible to state definitely the composition of commercial ice cream, as it depends upon the ingredients used by the manufacturer. The materials used and the formulae adopted vary with the individual responsible, and as a result there is no standard composition. In all cases, however, commercial ice cream must contain milk fat, or the fat of milk, the minimum amount being specified by law in most states of the United States. A high-grade commercial ice cream will contain about 14 per cent milk fat. This means that milk and cream, or milk products, constitute the principal ingredients.

Commercial ice cream, being made principally from milk and cream, will contain in addition to milk fat, milk solids-not-fat or serum solids. When it is intended to include all the solids contained in ice cream, the term "total solids" is used, which includes the fat, the milk solids-not-fat, and all other solids added to the ice-cream mix from other sources. Sugar is included when the total composition of ice cream is discussed, because it makes up a large portion of the mixture.

In commercial ice cream a so-called "binder" or "stabilizer" is added. This tends to prevent the formation of water crystals. Flavoring extracts, chocolate, fruits, nuts, candies, and bakery products are added to ice cream for their flavoring effect. Summing up, therefore, the composition of ice cream is as follows: milk fat, milk solids-not-fat or serum solids, sugar, binding, and flavoring materials. The term "ice-cream mix" is commonly used to designate the complete mixture of ingredients which when frozen is known as ice cream.

The Ingredients Used in the Manufacture of Ice Cream. Milk and milk products are the principal ingredients used in manufacturing ice cream. They are the source of milk fat and milk solids-not-fat and furnish approximately 60 per cent of the total solids of the ice-cream mix. The milk products commonly used in ice cream are cream, skim milk, butter, condensed and dried milks. Cream is used primarily because it is the best source from which to secure the milk fat in concentration for use in ice cream. When cream is not available, the milk fat may be secured from butter or butter oil, but, as a rule, the use of butter or butter oil in ice cream can be detected, and where an ice cream of the best quality is being manufactured, a high-grade cream is preferred.

Whole milk may be used in combination with cream; when used it generally is added to supply a portion of the fat and furnish the ice-cream mix with milk solids-not-fat or serum solids. The lower the percentage of fat in the cream used in the ice-cream mix, however, the less milk is required. For this reason, the manufacturer often purchases cream of a low fat content for use in ice cream. Since cream is usually purchased on the basis of its fat content, the practice of buying low-testing cream permits the ice-cream manufacturer to secure milk solids-not-fat at a relatively low cost. When cream must be shipped to the ice-cream plant over long distances, however, cream of a high test (40 per cent) is preferred. The increased cost of transportation to the ice-cream manufacturer of low-testing cream more than offsets the cost of milk solids-not-fat so gained. Furthermore, high-testing cream has the advantage of possessing better keeping qualities than low-testing cream and requiring less space in storage.

Condensed and dried milks are used in ice cream to supply the mixture with milk solids-not-fat. Due to the fact that commercial ice cream is generally high in milk solids-not-fat, these constituents must be added to the mix in concentrated form. If the condensed or dried milk is made from whole milk, the butterfat content of both must be taken into consideration in calculating the ice-cream mix.

Quality of Dairy Products for Ice Cream. All dairy products used in the manufacture of ice cream should possess a clean, sweet flavor indicative of sanitary methods of production and handling. A high-grade ice cream cannot be made from poor quality raw products. A sour milk or cream never should be used in ice cream. Most off-flavors occurring in milk or milk products are intensified after freezing. In some instances they may be masked slightly by making a chocolate or caramel ice cream. Such a practice, however, should not be encouraged.

Sweeteners for Ice Cream. The most common sweeteners used in commercial ice cream are cane and beet sugar. The amount of sugar used varies with the judgment of different manufacturers. It is generally recognized, however, that ice cream should contain at least 12 per cent sugar. The sugar content also affects the smoothness of the resulting ice cream and for this reason many manufacturers add as high as 17 or 18 per cent of cane sugar to the ice-cream mix. A very good ice cream results when 14 to 16 per cent of sugar is used.

Corn sugar, corn syrup, or maltose syrup and honey can be used to sweeten ice cream or as substitutes for a portion of the common sugar required. The practice of using these sweeteners is not considered practical or economical when cane or beet sugar can be purchased at normal prices.

Ice-cream Stabilizers. By experience, the manufacturer of commercial ice cream has found it advantageous to add to ice cream some material which will tend to hold ice cream in shape after it has been served. Such products are known as "stabilizers" or "binders." Gelatin and sodium alginate are used most, with gelatin the more widely accepted. Gelatin is known to the chemist as a colloidal substance. It has the property of absorbing large quantities of water in proportion to its own weight. Such a mixture of water and gelatin will form a jelly when allowed to set. This property of gelatin is advantageous in the manufacture of ice cream as it will retard the formation of ice crystals during the freezing and hardening process. This results in an ice cream with a smoother body that will stand up better while it is being served.

Gelatin is not a cheap product and in no way cheapens the ice-cream mix. Public opinion was turned against the use of gelatin a number of years ago before the manufacturers of the product had given much consideration to its purity. Today, the gelatin used by the ice-cream manufacturer is identical with that used by the housewife and is a clean, wholesome product. It is a protein food which is readily digested.

Sodium alginate is of vegetable origin. It is prepared from the giant Pacific Coast kelp, *Macrocystis pyrifera*. As a stabilizer for ice cream it has proven very satisfactory. The chief advantage in its use is its immediate effect on the viscosity of the mix. By cooling promptly after pasteurization, a mix containing this stabilizer does not increase markedly in viscosity. This property permits the manufacturer to prepare a mix of more uniform viscosity from day to day, thus making it possible to standardize the freezing procedure.

Many other stabilizers have been suggested for use in ice cream and are used to a limited extent. There are such products as Irish moss, quince seeds, gum tragacanth, gum arabic, Karaya gum, oat gum, methylcellulose, and others.

Flavoring Materials. The common flavoring extracts used in the manufacture of ice cream are vanilla, strawberry, lemon, and raspberry. A high-grade extract used in ice cream should result in a pleasing flavor. Some of the flavoring extracts on the market, however, result in undesirable and disagreeable flavors.

Other materials such as chocolate or cocoa, coffee, bakery and candy products, fruits, and nuts, are used in ice cream in quantities pleasing to the taste. Eggs are seldom used in commercial ice cream, but may be utilized in the manufacture of fancy ice creams and custards.

Preparation of the Ice-cream Mix. The preparation of the ice-cream mix is a very important process in the modern ice-cream factory. At one time, the ice-cream mix was prepared by using a fixed formula. The common measure was the quart and gallon can. Cream and milk were used regardless of their fat content. No attention was given to the milk solids-not-fat which were placed in the mix when milk and cream were used. The result was an ice cream of irregular quality from day to day. Under such conditions it is impossible to apply business principles in a factory as the cost of the mix varies.

The modern ice-cream manufacturer is keen to make use of every fact developed by science. In the typical factory at present a technically trained dairy-products expert is usually employed. It is his duty to make a complete analysis of every product used, and to be responsible for maintaining a uniform composition from day to day. The important technical details are so generally known and understood that the procedure in the preparation of the commercial ice-cream mix can be set forth as typical for most ice-cream factories. These steps include the following: (1) calculation of the proportion of each ingredient that is to go into the mix; (2) pasteurization of the mix; (3) homogenization of the mix; (4) aging of the mix. After the mix has passed through these steps, it is ready for the ice-cream freezer from which it passes to the hardening room.

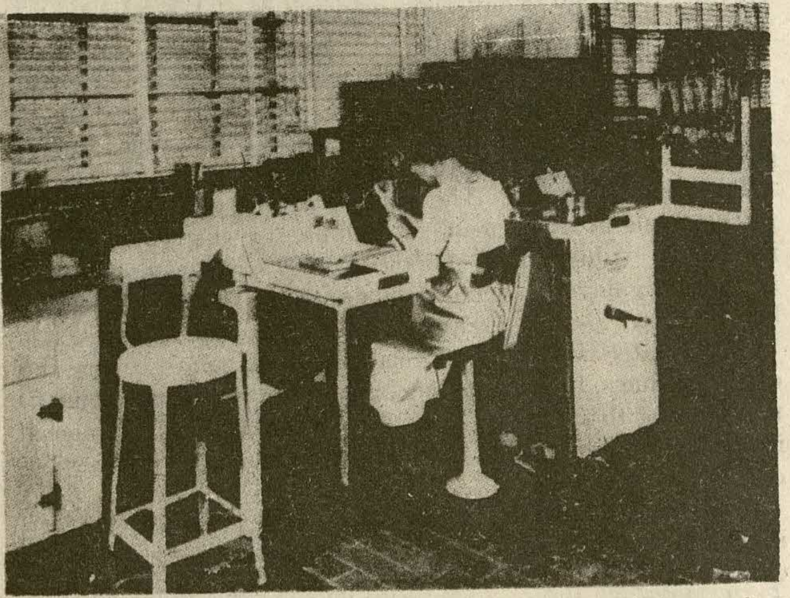

FIG. 74. An ice-cream laboratory. The large ice-cream manufacturer makes a complete analysis of the milk products which enter into the ice-cream mix. The composition of the mix is carefully controlled. (*Courtesy of Mojonnier Bros. Company.*)

Calculation of the Mix. After the composition of the mix to be used has been decided upon, the next step is to calculate the amount of each ingredient which is to be used. This part of the work must be done with great care for two very important reasons. First, a satisfactory quality in the finished product is possible only when the proper proportion of constituents is used in the mix. In order to retain the favor of consumers, the ice cream should always taste the same and have the same physical properties; that is, it must have a uniform quality from day to day. The consumer selects other kinds of ice cream for variety but expects a certain type of product, for example, vanilla ice cream, always to have the same characteristics.

The second important reason for giving so much attention to the calculation and preparation of the mix pertains to the cost. If a standard fat content of 12 per cent is required it is highly important to the manufacturer that the percentage of this expensive ingredient does not vary appreciably from the required standard. If through lack of proper control a fat percentage of 14 per cent were used, the additional cost might absorb practically all of the manufacturer's profits. If the fat percentage were inadvertently lower than the standard, not only would the quality of the product be lowered, but the manufacturer might be violating a city or state statute. The importance of this close control is more easily visualized by calculating the loss that 2 per cent extra fat in the mix would mean to a factory using 2,000,000 pounds of ice-cream mix yearly.

Technical Skill Necessary. The difficulties encountered in standardizing the mix properly are such that most of the larger ice-cream manufacturers find it profitable to employ for the purpose a man who has had technical training in science and dairy technology. The difficulties to be overcome in preparing a mix of definite composition will be better realized when it is pointed out that the products to be used may include cream, whole milk, concentrated whole milk, skim milk, sugar, gelatin, and flavoring. Furthermore, the first three may vary in composition from day to day. With these ingredients at hand, the problem is to calculate a mixture that will contain a uniform percentage of fat, total solids, and sugar.

Procedure in Calculating a Mix. It is clear that, first of all, an analysis of the products to be used must be made. For example, milk fat might be supplied from three sources: cream, milk, and concentrated whole milk; the milk solids-not-fat of the mix may be supplied by these same constituents and skim milk; sugar and gelatin also may be used. Almost any group of dairy products may be used as sources of fat and milk solids-not-fat. If the fat of the mix is secured from but one source, for example, cream, the problem is simplified. It is essential, however, in most instances that the milk solids-not-fat be secured from two or more sources.

A Problem in Preparing a Mix. To illustrate briefly to the reader an ice-cream problem, let it be assumed that it is desired to make 100 pounds of mix to contain 14 per cent fat, 38 per cent total solids, 15 per cent sugar, and 0.5 per cent gelatin. It is necessary, first, to calculate the percentage of solids in the proposed mix which will be in the form of milk solids-not-fat. This figure is obtained by subtracting the total of the fat, sugar, and gelatin (29.5 per cent) from the total solids (38 per cent), which gives 8.5 as the percentage of milk solids other than fat.

It will be assumed that analyses already made show that there is available to go into the mix: cream, containing 40 per cent fat and 45.5 per cent total solids; plain condensed whole milk, containing 11 per cent fat and 35 per cent total solids; and skim milk, containing 8.5 per cent total solids. There are several methods by which this problem may be calculated. The use of algebraic equations, however, gives the exact amount, while other methods are more of an approximation.

As the unit selected is 100 pounds of mix, it is clear that the amount of sugar and gelatin needed is the same as the desired percentage of these ingredients, that is, 15 pounds of sugar and 0.5 pound of gelatin.

To find the pounds of the other ingredients needed, algebraic equations are formed:

Let x = pounds of cream required in the mix.
y = pounds plain condensed whole milk.
z = pounds of skim milk required.
15 = pounds of sugar.
0.5 = pounds of gelatin.

It is clear the sum of these is 100. Other equations may be formed, one representing the fat, another the total solids. By this means three simultaneous equations are formed which involve the same unknowns, for example,

$$x + y + z + 15 + 0.5 = 100. \qquad (1)$$
$$0.40x + 0.11y = 14. \qquad (2)$$
$$0.455x + 0.35y + 0.085z + 15 + 0.5 = 38. \qquad (3)$$

Of these, equation (1) represents the total mix. It is clear that the pounds of cream, concentrated whole milk, and skim milk required, together with the 15 pounds of sugar, and 0.5 of gelatin should total 100 pounds.

Equation (2) is the fat equation. Fat is supplied by the cream with a fat content of 40 per cent and the concentrated whole milk containing 11 per cent of fat. The mix is to contain 14 per cent.

The third equation represents the total solids. Solids are supplied by all ingredients. A fixed amount is to be supplied by the gelatin and sugar and the amount present in the other ingredients to be used is known. The cream contains 45.5 per cent solids, the plain condensed milk 35 per cent, and the skim milk 8.5 per cent. The equation will be:

$0.455x$ (total solids to be supplied in cream) $+ 0.35y$ (total solids from concentrated milk) $+ 0.085z$ (total solids from skim milk) $+ 15$ (pounds of sugar) $+ 0.5$ (pound of gelatin) $= 38$.

By solving these three equations, it is found that

$$x = 31.01,\ y,\ 14.51 \text{ and } z,\ 38.98.$$

These figures are the pounds of the cream, the concentrated milk, and skim milk required, together with the sugar and gelatin to make 100 pounds of the mix with the composition as specified. The proof of the problem is given in the following statement:

Ingredients	Pounds used	Pounds, fat	Pounds, total solids	Pounds, sugar	Pounds, gelatin
Cream	31.01	12.40	14.11	0	0
Plain condensed milk	14.51	1.60	5.08	0	0
Skim milk	38.98	0	3.31	0	0
Sugar	15.00	0	15.00	15	0
Gelatin	0.50	0	0.50	0	0.5
Total	100	14	38	15	0.5

In commercial practice, the calculation of the mix is often simplified by using milk products of uniform composition. Flavoring is added to the mix at the freezer and generally is not included in the calculation.

Pasteurization of the Mix. The ingredients which are to make up the mix are placed in a mixing vat in preparation for pasteurization. As a general rule, the viscous fluids are placed in the vat first, followed by the less viscous fluids. Sugar and gelatin are added last. After all ingredients going into the mix are in the vat, the entire mixture is heated to a temperature of 155 to 165°F. (68.3–73.9°C.), and held from 25 to 30 minutes. The mix then is rendered homogeneous by passing through a machine such as the homogenizer or viscolizer.

Homogenizing the Mix. The homogenizer consists of a series of pumps which draw the mix into small chambers from which it is forced out, under considerable pressure, through a small needle valve. The pressure ranges from 2,000 to 4,000 pounds per square inch. The action of these machines is primarily on the fat of the mix. The globules are reduced many times in size. In fact, cream or ice-cream mix is very difficult to churn after homogenizing. Ice cream made from a homogenized mix appears slightly richer in fat, and is much smoother and more velvety than if unhomogenized. Immediately after homogenizing, the mix is cooled to a temperature of 40°F. (4.44°C.) or lower.

Aging the Mix. The mix, after being homogenized and cooled, is aged for a period of 4 to 24 hours. During the summer months the shorter period is used because of the higher acidity which, generally, is naturally present in milk and cream and due to need of rushing the mix to the final state of ice cream to meet the demand. Aging results in a mix taking on an increased viscosity and a glossy, smooth appearance. It further assists in improving the smoothness of the finished product. A certain amount of viscosity is essential, also, in securing an overrun in the manufacture of ice cream. A mix should not have too much viscosity, however, as under such circumstances difficulty is experienced in securing the swell or overrun. The viscosity of the mix is increased by homogenizing and by aging. It is impossible, however, to accomplish the same results with the homogenizer that are obtained by aging, as the one is a mechanical action, and the other a chemical or colloidal action.

Freezing the Mix. There are two general types of ice-cream freezers available on the market for use in freezing ice cream, namely, the "batch" and the "continuous" freezers. The batch freezer is the more commonly used, while the continuous type is adaptable for use in factories producing a relatively large volume of ice cream. The batch freezers are made in capacities ranging from 20 to 160 quarts, while the continuous freezer—made as the name implies to freeze continuously—ranges in capacities from 75 to several hundreds of gallons of ice cream per hour. The batch freezer consists of a double-walled cylinder which is fixed firmly on a base. Inside the cylinder are dashers which scrape the frozen material from the walls and keep the cream thoroughly mixed. They also serve to beat air into the freezing mixture. Flavoring extracts, as fruits or nuts, if used, are generally added during the process of freezing.

Freezing of the ice-cream mixture is accomplished by circulating cold brine or by allowing ammonia to expand directly around the walls of the cylinder surrounding the mix. As the mixture freezes, it thickens. When the ice cream in the freezer thickens to a consistency of a semisolid, the brine or ammonia is shut off and allowed to by-pass through a pipe line along the side of the freezer. By allowing the dashers to keep in motion, air is whipped into the semifrozen mixture, causing it to swell in volume. When the desired swell, or overrun, as the ice-cream manufacturer terms the increase in volume, is secured, the ice cream is allowed to flow from the freezer into containers in which the ice cream is sold, or into containers from which it can be quickly removed before placing in a final package. It is then placed in a cold room, commonly referred to as the "hardening room," which is maintained at a temperature of −10 to −20°F. (−23.33 to −28.89°C.), or lower.

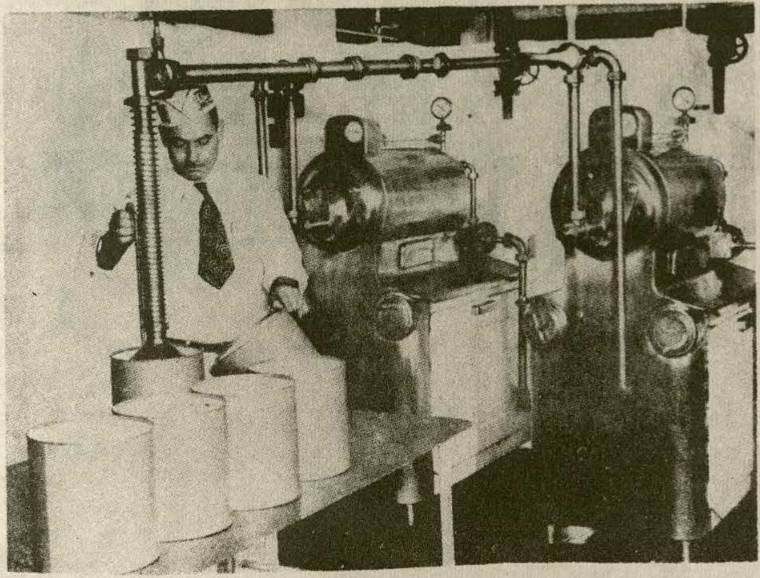

FIG. 75. View of the freezing room in an ice-cream factory. Two continuous freezers are shown. (*Courtesy of Cherry-Burrell Corporation.*)

The continuous freezer is more complicated than the batch freezer. It is designed to freeze a small stream of the ice-cream mix as it flows through the machine. The freezing is continuous. Swell or overrun is regulated by incorporating air into the mix by means of an air pump. Fruits, etc., are added to the frozen mix as it flows from the machine. The mix is frozen to the desired state in a few seconds after entering the machine.

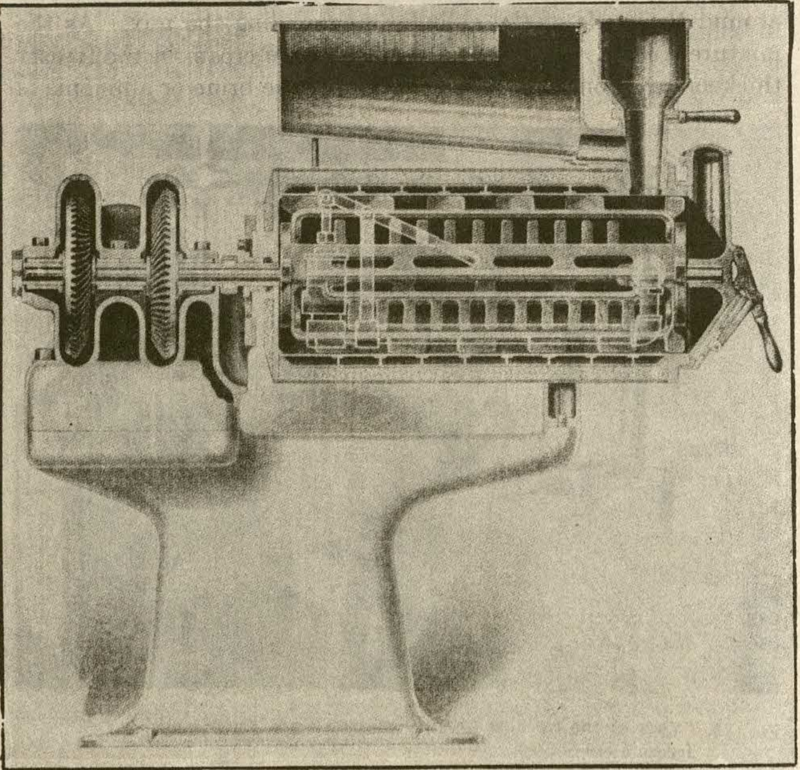

FIG. 76. Sectional view of a commercial batch ice-cream freezer. The view shows the cylinder surrounded with insulation material, the wall between the outer cylinder and the inner cylinder through which a cold brine passes, and the dasher which keeps the mix agitated and whips air into the partially frozen mixture. After freezing to a semisolid mass the mix is allowed to flow out of the gate at the right end. (*Courtesy of the Creamery Package Manufacturing Company.*)

Freezing is completed in the hardening room, as indicated above. The rate at which the ice cream is frozen in the freezer and in the hardening room has a direct bearing on the fineness of the texture of the finished ice cream. The faster the freezing, the smaller the ice crystals formed and the smoother the texture of ice cream. In recent years there has been a tendency toward quick freezing. This is accomplished in the hardening room by circulation of the air at a high velocity. Not only does such a practice result in quick freezing, but it is a more economical procedure.

Bulk and Packaged Ice Cream. As indicated above, the ice cream is allowed to flow from the freezer into the package in which it is sold. This is particularly true of ice cream, sherbet, or fruit ice sold in bulk containers which hold from 1 to 10 gallons. The common bulk container is the 5-gallon ice-cream can or fiber package. The retail distributor is accustomed to purchasing ice cream, sherbet, or fruit ice in such containers from which he may dip individual servings or fill pint or quart containers for the consumer. Small individual servings or pint, quart, and 2-quart containers may be filled at the factory. This is done either by filling the container with the semisoft frozen product at the freezer or by the use of specially designed packaging machines.

Packages filled by the retail distributor usually weigh more than similar packages filled at the factory. This is explained by the fact that the air incorporated in the freezer is partially lost when the frozen product is removed from the bulk package with small dippers and then pressed into a small container. The price charged by the retailer is frequently more than that charged for the "factory-packed" product to compensate for the loss in volume.

Brick Ice Cream Brick ice cream of a single flavor is prepared by filling brick-shaped containers, either pint or quart, at the freezer or by means of specially designed packing equipment. It is possible to fill the packages with different flavors from continuous freezers by running lines from two or three freezers into the containers held in proper position by a worker. This method of preparing brick ice cream has been adopted by the larger manufacturers. Small factories may prepare brick ice cream by drawing the semifrozen product into tin trays which hold from 1 to 8 quarts each. After the ice cream is allowed to complete the freezing in the hardening room, it is removed from the tin trays. Individual quarts are then wrapped in parchment paper and generally placed in a heavy waxed-paper carton. The ice cream removed from trays holding more than 1 quart is cut by hand or machine into 1- or 2-quart sizes which are placed in cartons. The small-factory operator who wishes to prepare bricks of two or more flavors of different colors will freeze one flavor and partially fill the brick trays to the point desired and place in the hardening room. When the freezer is emptied of the first flavor and the second is ready to be removed, the filling of the tray is completed. If three flavors or layers are desired, a third freezing must be made. The larger factories preparing brick ice cream in this manner can complete the operation very quickly as they generally operate several freezers at one time. The trays are filled to a given point from one freezer with one flavor and to another point from another freezer, until the tray is filled with two or more layers of ice cream.

Center bricks are prepared by filling forms, much as individual forms are prepared, as described below. The frozen center is set in position in soft ice cream. The brick form is then placed in the hardening room to complete the freezing of the soft ice cream.

Individual Forms and Packages. Ice cream is often made into shapes to represent various objects, such as flowers, fruits, melons, lodge insignia, etc. To prepare these individual forms, hollow molds are used. An individual mold consists of sufficient ice cream for one serving. Bulk ice cream is softened and the mold filled. It is then placed in a cold brine for a few minutes to reharden the softened ice cream. The mold is then dipped into cool water and the ice cream removed. The individual mold of ice cream is then placed in the hardening room and allowed to become thoroughly frozen for a second time. Ice cream of one solid color may be used, but if varying shades are desired on the finished object, this is done after the individual mold has been rehardened. In addition to the individual forms, ice cream is also placed in small cups which hold sufficient for one serving and in which it can be sold at public places.

Following the plan mentioned in connection with the individual forms, ice cream can be prepared in any shape to suit a given occasion. Not only individual forms are prepared in this manner, but forms of sufficient size to serve a number of people.

Quality of Ice Cream. Ice cream is not graded on the market, as it is sold by the manufacturer directly to the retailer or

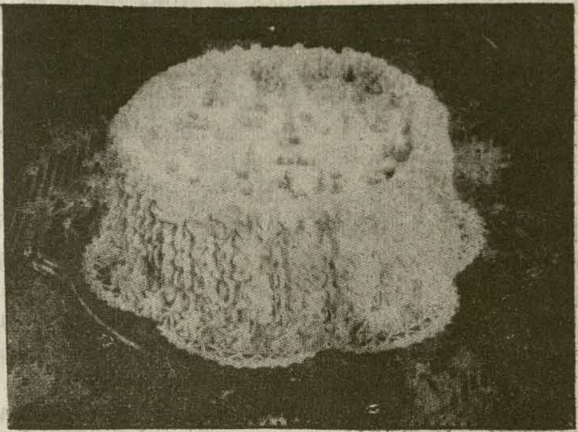

FIG. 77. A birthday cake of ice cream. **The cake consists of two or more layers of ice cream and sponge cake or meringue covered with sweetened whipped** cream worked in fancy decorations.

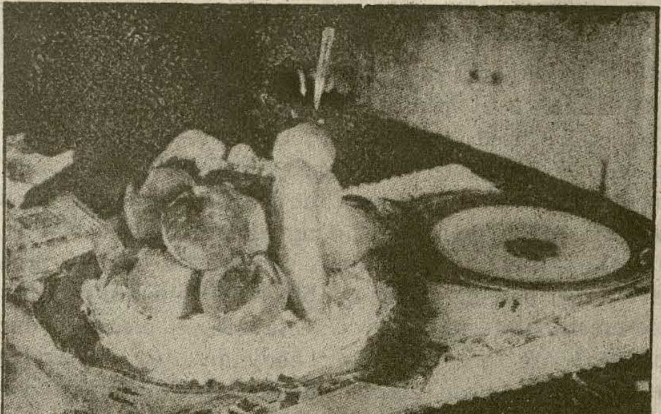

FIG. 78. Individual forms of ice cream. Individual forms of all shapes may be made of ice cream. A plate of fruit forms is shown in the illustration.

consumer. The qualities that constitute a good ice cream are left more or less to the judgment of the individual manufacturer and his ability to judge the preference of the public. In general, it is conceded that a high-quality ice cream should have a rich, creamy, sweet taste, be smooth of body, and close-textured

The richness of ice cream is influenced primarily by the fat content. If ice cream contains below 10 per cent of fat, it lacks richness. If too much milk fat is used, it will be too rich. An individual cannot eat a very large serving of ice cream when it contains much more than 14 per cent of milk fat. Because of this fact, commercial ice cream seldom contains more than 14 per cent of fat, and if the laws within the state in which it is sold will permit, a slightly lower fat content is to be preferred. As previously indicated, ice cream containing about 14 per cent of milk fat results in an excellent commercial product. Some fancy ice cream may contain as high as 18 to 20 per cent of fat.

The sugar, stabilizer, and milk solids-not-fat in ice cream contribute to its quality and palatability. The sugar content should not be below 12 per cent. The general public prefers an ice cream containing 16 to 18 per cent of sugar. For several reasons, it is not practical for the commercial ice cream to contain as much as 16 to 18 per cent of sugar. A good quality of commercial ice cream contains from 14 to 15 per cent. The milk solids-not-fat will range from 9 to 11 per cent in a high-quality ice cream, the gelatin or other stabilizer approximately 0.25 to 0.5 per cent, and the total solids content may range from 38 to 40 per cent. Eggs are sometimes used commercially, and contribute a certain richness and smoothness to the finished ice cream.

In addition to the influence of the constituents on the quality of an ice cream, the quality of the ingredients used in the mix, and the method of caring for the mix through the various processes have a direct bearing on the quality of the finished product.

Ice-cream Defects. The defects in ice cream commonly referred to are those of flavor, body and texture, and color. The flavor of ice cream is largely due to the flavor imparted by the ingredients used. Milk and milk products must be free from off-flavors. Off-flavors in milk or cream may become intensified in ice cream. Particularly is this true when ice cream of delicate flavors such as vanilla, peach, pineapple, etc., is made. Such off-flavors as metallic, old-cream, rancid, cooked, and bitter may be experienced in ice cream, due to the use of milk or milk products in which these flavors occur.

Other flavor defects are those due to using too much or too little of a given flavor. If ice cream contains too much vanilla, for example, the flavor imparted may be objectionable. If too little vanilla is used, there may be a lack of flavor. Flavor defects also may be due to the use of too large or too small an amount of the ingredients that go into the mix. Milk fat and sugar are examples of ingredients that may influence the flavor, one affecting the richness and the other the sweetness of the finished product.

Body and Texture Defects. The body and the texture of ice cream are commonly referred to as a single quality. Body refers to the whole structure and is largely influenced by the composition of the mix, while texture has to do with the makeup of the individual particles that form the entire body. To illustrate, two pieces of cloth may be made of the same material and be alike in every way so far as composition or the material of which they are made is concerned. They may differ, however, in that one is more closely woven than the other, or in the fineness of the threads used in their construction. The common defects of body and texture in ice cream are not only due to the material but to the processes used in its manufacture. Although it is difficult to describe accurately the ideal body and texture desired in ice cream, there are a number of defects which are generally recognized and detected. Such defects may be listed as follows: soggy, gummy or sticky, weak, coarse, fluffy, watery, crumbly, and icy. In addition, ice cream may become sandy, a defect which is due to the crystallization of the lactose of the mix and which when eaten, grits on the teeth like sand. Buttery body and texture is a term used when it is desired to convey the idea that there are particles of butter in the finished ice cream.

Color Defects. Ice cream should possess a pleasing color. If its color is too high or if it lacks color, it is objectionable. When ice cream is colored to represent the shades of various fruits, the color should be "natural." In addition, the color should be evenly distributed.

Distribution of Ice Cream. Unlike other milk products, ice cream is not generally transported over long distances. It is more economical to ship the products of which ice cream is made to a point from which the finished ice cream can be easily distributed. This is because ice cream, a fairly bulky product, must be kept in a frozen state until it reaches the consumer. Refrigerated, insulated trucks are commonly used to transport ice cream from the manufacturer to the retail distributor. Packaged ice cream is often packed with dry ice (solid carbon dioxide) in insulated bags or corrugated boxes for wholesale and retail distribution. Before the introduction of mechanically refrigerated trucks of different designs and solid carbon dioxide, ice cream was packed in containers surrounded with ice and salt to insure holding it in a frozen state for distribution. This method is used only to a limited extent today.

Ice-cream Making in the Home. Ice cream is easily made in the home. Recipes for small quantities of finished ice cream may be found in most reliable cookbooks. The home recipes differ materially from the formulae used commercially, particularly in the use of starch, so-called "ice-cream powders," and arrowroot flour. Eggs are generally included in the home recipe but are not so common in commercial ice cream. Dry egg yolk is the more common form in which eggs reach commercial ice cream. More modern cookbooks recommend the making of ice cream which is more like modern commercial ice cream. Such recipes include dried or condensed milk and gelatin in the ice-cream mix, together with milk, cream, and sugar.

Too frequently, in the home it is the practice to prepare the ice-cream mix and freeze immediately. Such a procedure results in a coarse, grainy ice cream. To overcome this defect of homemade ice cream, the mix should be aged for 24 to 48 hours at a low temperature. This procedure is not always possible in the home, nor is it convenient. It is therefore advisable in making ice cream in the home to use a recipe which includes eggs, and to prepare a custard. The custard is heated in a double boiler to a point at which the mixture starts to thicken, after which it is cooled. The mixture is agitated during the heating and cooling.

To freeze ice cream in the home, the small hand or motor-driven freezer is used. The can in which the cream is frozen is filled about half-full with the ice-cream mix. This permits the incorporation of air or the swelling of the mix during the freezing process. A mixture of cracked ice and coarse salt, consisting of about 1 part of salt to 5 or 6 of ice, should then be placed around the can. Cool water should then be poured over the ice and salt and allowed to come to a point well above the point at which the ice-cream mix comes in the freezer can.

The freezing process should be slow in the beginning and until the mixture starts to thicken. This will require 6 to 8 minutes.

The freezer should then be turned rapidly until the freezing is completed. The slow freezing is intended to cool the ice-cream mixture to a point near its freezing point, while the rapid freezing completes the cooling process and whips air into the mixture. If possible, the freezing should stop when the frozen cream can be readily removed from the dasher with a knife or spoon. The ice cream is then packed in ice and salt and allowed to complete freezing before being consumed. This should require about 1 hour.

The household, mechanical refrigerator has been recommended to the housewife as a method of preparing ice cream. For best results, the chilled and aged ice-cream mixture should be placed in the ice trays and the controls set for a low temperature. After the mix is partially frozen, it should be removed from the box and placed in a chilled bowl and whipped. It is then transferred to the ice tray and placed in the freezing compartment to complete freezing.

Several mechanical freezers are available to the householder for making ice cream. These are motor-driven and are designed to handle approximately 1 gallon of finished ice cream.

Microbiology of Ice Cream. The microörganisms that may be present in ice cream and related frozen delicacies are of importance mainly from the standpoint of health or as criteria of the quality of the ingredients and methods of handling within the factory. Inasmuch as these frozen products are stored at temperatures much too low to permit the development of microörganisms, their deterioration is not due to microbiological agencies.

The numbers of bacteria which are present in ice cream will depend very largely upon the numbers and types in the raw materials, especially milk, cream, condensed or dried milk, the efficiency of pasteurization, and the extent of contamination from various pieces of equipment with which the product comes in contact. At times, a poor grade of gelatin, condensed or dried milk, or unsalted butter may contribute significant numbers of organisms. Flavoring extracts, fruits, nuts, chocolate, colors, etc., which may be added to the pasteurized mix occasionally may be responsible for increases in the bacterial count of the ice cream.

Number of Bacteria in Ice Cream. The pasteurization of the complete mixture of the principal ingredients of ice cream, including the milk products used, sugar, and gelatin, will reduce decidedly the numbers of microörganisms. Particular attention must be paid to the possible presence of heat-resistant (thermoduric) bacteria which may reduce the effectiveness of pasteurization. If high-grade flavoring, fruits, etc., are added and if the equipment through which the product passes is thoroughly sterilized, it is possible to obtain an ice cream with a reasonably low count. In fact, it is not at all difficult to manufacture ice cream under commercial conditions with a count below 100,000 bacteria per milliliter.

The homogenizing process tends to cause an apparent increase in count due to the breaking up of clumps of bacteria, even when the apparatus is sterile. This is much the same sort of phenomenon as described under the process of clarification. A similar increase in count may occur in the freezer. It must be borne in mind, however, that these increases are apparent rather than real, providing the appliances are not contributing bacteria. The change in count must not be confused with changes in actual numbers.

When the ice-cream mix is aged at temperatures below 40°F. (4.4°C.) before freezing, no appreciable increase in numbers is noted unless it is allowed to remain too long at temperatures above 32°F. (0°C.). After the product is frozen, transferred to the hardening room, and maintained at temperatures below 0.°F. (−17.8°C.), no growth of bacteria is to be expected. If the ice cream is allowed to melt and remain at temperatures above the freezing point, growth may be resumed; but this seldom occurs under practical conditions.

Importance of Bacteria in Ice Cream. Ice cream should be made from high-grade raw materials and be handled as carefully as any dairy product, even though low temperatures protect it against deterioration in storage.

The principal concern which the ice-cream industry has in microörganisms is from the standpoint of health. It is possible that the ingredients or the finished product may be infected with disease-producing bacteria which may not be affected adversely by the low temperatures, but remain capable of producing disease among the consumers of ice cream. To insure the proper pasteurization of ice-cream mix, as well as sanitary procedures in handling and processing the mix following pasteurization, several states have passed laws setting bacterial standards for ice cream.

CHAPTER XIII

THE MANUFACTURE OF DAIRY PRODUCTS (*Continued*)

CONDENSED MILK, DRY MILK, MILK BY-PRODUCTS

CONDENSED MILK

The manufacture of condensed milk, or milk from which a portion of the water is removed, is of comparatively recent origin. This method of preserving milk was introduced on a commercially successful scale by Gail Borden, who was granted a patent on the process in 1856, in the United States and England. The original patent included the concentration of milk by evaporation under vacuum without the addition of sugar or other foreign material. It appears, however, that the first milk manufactured by Borden for sale contained added sugar. Shortly

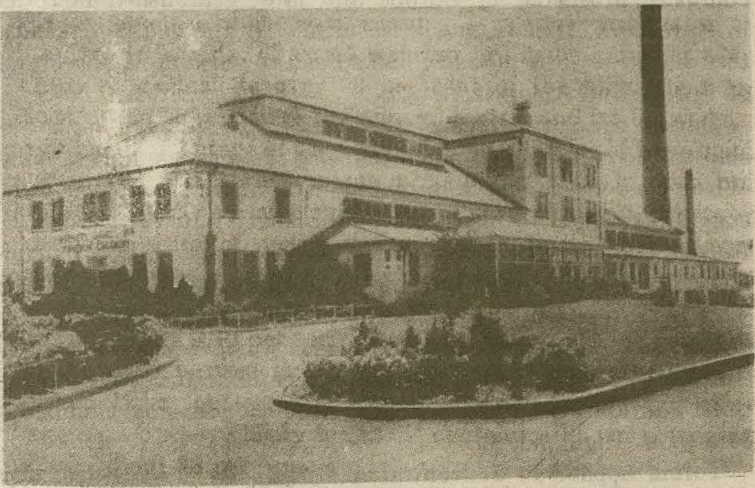

FIG. 79. A modern condensing and milk-drying plant. This organization is equipped to receive whole milk. The milk is separated and the cream shipped to an eastern market. The skim milk is condensed, in which form it may be sold or dried by either the spray or the drum process. (*Courtesy of Cameron Creamery Company.*)

afterwards (1858) Borden offered for sale in New York City and Brooklyn condensed milk at 25 cents per quart.

The first condensed-milk plant was established by Borden in 1856 at Wolcottville, Conn. This factory was in operation only for a short time. In 1857, Borden, and those with whom he had become associated, established a factory at Burrville, Conn., about 5 miles distance from the first factory. This second venture failed, but in February, 1858, Borden became associated with Jeremiah Milbank, in a third venture at Wassaic, N.Y. This company was known as the New York Condensed Milk Company and later was succeeded by Borden's Condensed Milk Company.

Shortly after the establishment of the New York Condensed Milk Company, a factory was established at Cham, Lake Zug, Switzerland, under the direction of George H. Page. This company prospered in Europe and later established factories in New York, Illinois, and Wisconsin. By the end of the nineteenth century, the industry had spread to various other sections of Europe and America.

During the early days of the industry, condensed milk was sold to the consumer in much the same manner as market milk. When condensed milk was placed in hermetically sealed cans, sugar was added to insure its preservation. In 1884, John B. Meyenberg was granted a patent for the preservation of condensed milk which was based on the sterilization of milk by heat. This invention made possible the placing of unsweetened condensed milk in hermetically sealed cans which became known as "evaporated milk." The first factory manufacturing evaporated milk was known as the Helvetia Milk Condensing Company, located at Highland, Ill.

Terms Applied to Concentrated Milks. By the removal of a portion of the water from such products as whole milk, skim milk, sweet or sour buttermilk, sour or cultured skim milk, and whey, the solids of these products may be concentrated into a much reduced volume. The process is known as "condensing" or "evaporating," depending upon whether a "vacuum pan" or an "evaporator" was used as a means of removing the water. Regardless of the method of concentrating, these products are recognized by the trade as "condensed milks." The following, more precise designations are used:

Plain Condensed Milk (Whole). Whole milk from which a portion of water is removed.

Plain Condensed Skim Milk. Skim milk from which a portion of the water is removed.

Superheated Condensed Whole Milk or Skim Milk. The product which results when whole or skim milk is condensed to a high concentration of solids, about 5 to 1, and then, while in the vacuum pan, subjected to a high temperature (about 185 to 190°F., (85 to 96°C.)) after which the solids are standardized to correspond to plain condensed milk.

Condensed Sweet-cream Buttermilk. This is the product that results upon the removal of a portion of the water from sweet-cream buttermilk.

Condensed Buttermilk. This is the product obtained when a portion of the water is removed from sour buttermilk.

Semisolid Buttermilk. This is the product which results when a relatively large proportion of the water is removed from sour-cream buttermilk so that the concentration of solids is about 5 to 1.

Condensed Whey. This is the product resulting from the removal of a portion of the water from whey.

Sweetened Condensed Whole Milk or Skim Milk. The addition of sufficient sugar to plain condensed whole or skim milk to insure preservation of the concentrated milk results in a product known as "sweetened condensed whole milk" or "sweetened condensed skim milk."

Evaporated Whole or Skim Milk. The term "evaporated whole milk" or "evaporated skim milk" is applied to the product which, after concentration to the desired ratio (about 2.1 to 1), is placed in hermetically sealed tins and subjected to high temperatures to insure sterilization.

Composition of Condensed Milk. In recent years, manufacturers of dairy products have practiced rather careful control of the products placed on the market. This is especially true of the condensed-milk industry. The composition of practically every lot sold is known and taken into account in a wholesale transaction. The composition of condensed milk is expressed in terms of (1) fat percentage, (2) total milk solids, (3) total solids, and (4) sugar (if added during the condensing process). The composition of the unsweetened is expressed in the first three terms; for the sweetened, the sugar percentage is also given.

Bulk sweetened condensed skim milk is sold on the market with a guaranteed minimum of 24 per cent total milk solids. Bulk sweetened, condensed whole milk is generally sold to contain a minimum of 28 per cent total milk solids and 8.0 per cent butter fat. The sugar content of these milks usually ranges from 40 to 45 per cent. Plain condensed whole milk is usually condensed to a ratio of 2.86 to 1, with a composition of 10 per cent fat, 26 per cent solids-not-fat, and 36 per cent total solids. Plain condensed skim milk is concentrated at ratios of 2.22 to 1, 3 to 1, and 3.78 to 1, or to a composition of about 20, 27, and 34 per cent total solids. The variation is due to the demand of users who may prefer a low, medium, or high concentration of solids. The superheated condensed milks, whole or skim, are generally concentrated to the same solids content as the plain condensed milks.

The percentage of milk fat and total milk solids in condensed milks is fixed by federal and state laws. According to the federal law, evaporated whole milk must contain not less than 7.9 per cent of milk fat and not less than 25.9 total milk solids, provided that the sum of the percentage of milk fat and total milk solids be not less than 33.8 per cent. Sweetened condensed whole milk must contain not less than 8.5 per cent milk fat and not less than 28 per cent total milk solids. The federal law requires evaporated and sweetened condensed skim milk to contain not less than 20 and 24 per cent total milk solids respectively. As a general rule, the manufacturers of these condensed milks adhere very closely to requirements as set forth by the federal laws.

The composition of evaporated and sweetened condensed milks is presented in more detail in the following statement:[1]

	Water, per cent	Protein, per cent	Milk fat, per cent	Lactose, per cent	Ash, per cent	Sucrose, per cent
Evaporated whole milk...	73.40	6.54	8.24	9.93	1.54	
Evaporated skim milk....	71.05	11.16	0.45	14.94	2.40	
Sweetened condensed whole milk............	26.75	7.85	8.99	12.94	1.77	40.59
Sweetened condensed skim milk.................	28.74	9.14	1.01	18.18	2.05	40.88

Properties of Condensed Milks. The chief difference between the properties of condensed milk and those of the milk from which it is made is found in the physical properties. This is observed, primarily, in the increased viscosity of the condensed milks. The sugar added to sweetened condensed milk increases the consistency of this type to a thick syrup-like mass. The concentration of the milk solids and the influence of the heat used in condensing in the presence of a slightly increased acid, due to concentration, is responsible for the increase in viscosity in unsweetened condensed milk.

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[1] "Fundamentals of Dairy Science," 2d edition, Reinhold Publishing Corp., New York. Table by Wright, Research Laboratories, Bureau of Dairy Industry, Washington, D.C.

Superheated condensed milk is extremely viscous due to the partial coagulation or jelling of the casein of milk, as a result of having been subjected to relatively high temperatures after condensing. In the manufacture of evaporated milk, sterilization is accomplished by subjecting the condensed milk to high temperatures under pressure. The increase in the viscosity in evaporated milk not only is attributed to the increase in the concentration of the milk constituents but to the hydrophilic condition of the casein which is even more pronounced than in the other unsweetened condensed milks. Evaporated milk is, therefore, subjected to vigorous shaking after sterilization in order to break the curd into a smooth, uniform mass. There may be a slight alteration in the sterilized evaporated milk that may be observed by the slight brownish discoloration and by taste. Due to the fact that evaporated milk is passed through an homogenizer before being placed in cans, the milk-fat globules are many times smaller than those present in normal milk and no cream appears on standing.

Method of Condensing Milk. Milk boils at a temperature slightly above 212°F. (100°C.) at ordinary atmospheric pressure. Milk, to be condensed, must be boiled, but to use a temperature of 212°F. (100°C.) would be injurious to the finished product. Condensing of milk, therefore, is conducted in a partial vacuum. By placing the milk under conditions of reduced pressure it boils at lower temperatures, according to the well-known principles of physics. On a mountain 10,000 feet high, water boils at a temperature of 193°F. (89.4°C.), which explains the difficulty experienced in cooking meats or in boiling an egg so that it becomes hard at high altitudes. By placing milk under 25 inches of vacuum, as is done in condensing, its boiling point is reduced from a point slightly above 212°F. (100°C.) to about 130° to 145°F. (54.4 to 62.78°C.). The milk then can be boiled vigorously and by providing means for causing the milk to spray in a fine mist and for carrying off the vapors rapidly, a large percentage of the water of milk can be removed quickly. The process is known as "condensing," and is carried on in various types of condensers and evaporators. The principal machine used for the purpose is known as the "vacuum pan."

The Vacuum Pan. The vacuum pan is constructed of copper, steel, or more often, stainless steel. It consists of a cylindrical retort from 3 to 7 feet in diameter, which is placed in a perpendicular position. The bottom of the retort is double walled, slightly concave, and known as the "jacket." Live steam enters this point of the jacket and contributes a portion of the heat required to raise the temperature of the milk to the point at which it boils in the pan. On the inside of the pan, above the jacket, are placed several coils through which live steam passes during the condensing process. Above the coils is the main body of the pan in which the boiling milk rises and sprays before dropping back

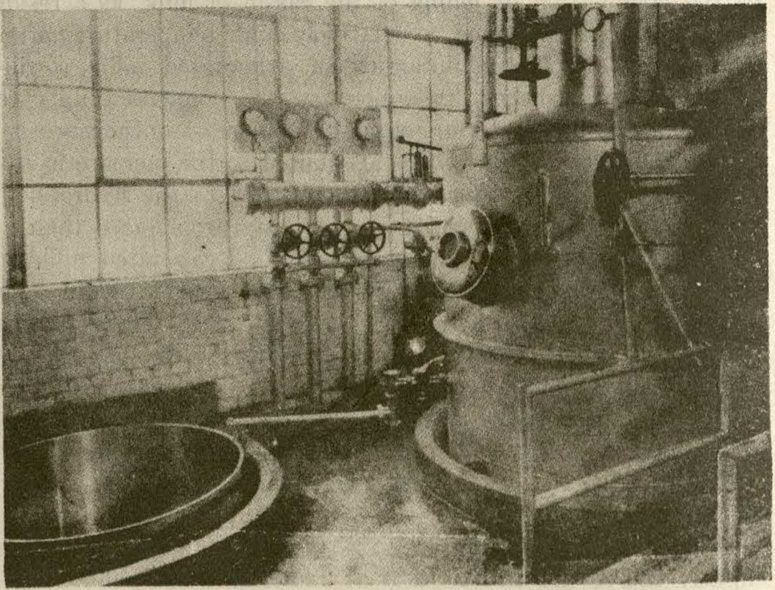

FIG. 80. Inside view of a milk-condensing plant showing the vacuum pan. The tank to the left is the hot well where the milk is preheated before it is drawn into the vacuum pan. The lower section of the vacuum pan extends to the floor below. (*Courtesy of C. R. Rogers Company.*)

toward the jacket to repeat the process. A glass peephole is set in the pan at this point to permit the operator to observe the milk during condensing. A manhole also is set at this point to permit a man to enter the pan to clean it.

At the top of the pan is located the dome in which is placed the condenser. The condenser is constructed so that the vapors of the boiling milk are drawn into a trough into which cold water is allowed to spray, thus causing the vapors to condense. From the condenser, the water passes out of the pan to the sewer. A vacuum pump connected with the pan maintains a vacuum of about 25 inches when the milk is at a temperature of about 135 to 140°F. (57.2 to 60°C.).

Many improvements have been made in the construction of the vacuum pan as described above. The principal improvements are to be found in accessories intended to increase the velocity of milk and steam. Major changes, however, have been made in construction, such as the elimination of the "jacket" and the installation of numerous flat, or oval-shaped, short coils.

In addition to the type of vacuum pan described above, there are on the market others which may be grouped under the term "rapid-circulating vacuum pans" and "tubular evaporators." These pans have neither jacket not steam-heating coils, but the lower section of the pan consists of a steam chest in which are placed a number of straight tubes. Milk enters the tubes under vacuum and, on boiling, a spray of hot milk is thrown from the tubes into the body of the pan. (This section is often known as the "vapor chamber.") The vapors are removed by means of a condenser somewhat similar to that used in the other type of vacuum pan. The milk returns to the tubes in a steam chest by means of another route, and the process continues until the milk is concentrated to the proper point.

The Process of Condensing in a Vacuum Pan. Milk intended for condensing is placed in a tank, commonly termed the "hot well," where it is heated to a temperature of 145°F. (62.78°C.) to 230°F. (110°C.); (varying temperatures are used at the hot well in making the various types of condensed milk, with 167 to 185°F. (75 to 85°C.) best). The pan, generally, is heated by permitting steam to enter the pan through a pipe line provided for the purpose. About 25 inches of vacuum are drawn on the pan and the water started through the condenser. Milk enters the side of the pan through a pipe line leading from the hot well to the pan. By means of the vacuum, the milk is sucked into the pan. When the jacket is covered with milk, the steam is turned into this section. The steam is turned into the coils as they are covered with milk. The heat currents entering the milk from the bottom and sides cause it to boil vigorously, and to acquire a definite course upward and towards the center and then downward. The vigorous boiling, together with the cross-currents of heat met within the pan, causes the milk to be thrown in a spray as it goes upward, thus increasing materially the rate at which the water evaporates from the milk.

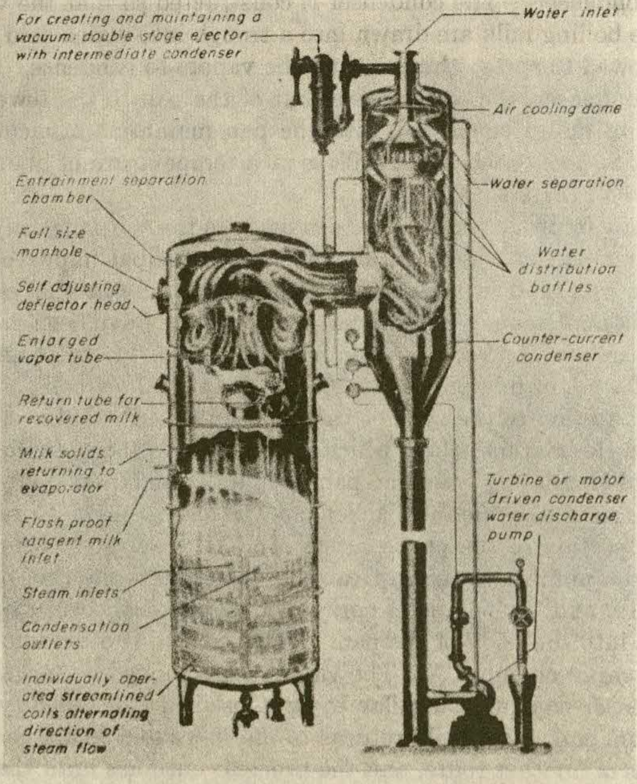
For creating and maintaining a vacuum: double stage ejector with intermediate condenser
Water inlet
Air cooling dome
Entrainment separation chamber
Water separation
Full size manhole
Water distribution baffles
Self adjusting deflector head
Enlarged vapor tube
Counter-current condenser
Return tube for recovered milk
Milk solids returning to evaporator
Turbine or motor driven condenser water discharge pump
Flash proof tangent milk inlet
Steam inlets
Condensation outlets
Individually operated streamlined coils alternating direction of steam flow

FIG. 81. Milk-condensing equipment. A diagrammatic view of a condensing or vacuum pan. (*Courtesy of Arthur Harris and Company.*)

A valve connection on a pipe line entering the bottom of the pan permits the drawing off of the finished condensed milk.

The condensed milk is not removed from the pan, however, until the proper concentration is reached. This is determined from the specific gravity of the product. In practice, an instrument known as the Baumé hydrometer is used. By making frequent chemical analyses of condensed milk and observations of the Baumé reading at definite temperatures, it is possible to determine the exact point at which to withdraw the condensed milk from the vacuum pan to secure a finished product of a definite composition.

Standardization of Condensed Milk. The condensed-milk manufacturer is particularly careful that the finished product have a definite composition. Not only is close attention given to the butter-fat content, but the milk solids-not-fat are checked closely by chemical analysis. The same may be said of the sugar content of sweetened condensed milk. It is not unusual for a condensary to handle 100,000 pounds of milk daily. It is highly important, therefore, that the composition of the product be closely checked.

Milk for condensing is analyzed for butter fat and total solids. The ratio of fat to solids-not-fat is calculated. A definite amount of fat and milk solids-not-fat is desired in the finished condensed milk. If the normal milk is too high in butter fat or too high in milk solids-not-fat, the ratio of these two constituents to one another can be adjusted either by the addition of butter fat or by the addition of milk solids-not-fat. Sweet cream or sweet-cream butter is used to raise the fat in proper ratio and skim milk or dried skim milk to adjust the milk solids-not-fat. There are times when the removal of cream is essential in the manufacture of condensed milk of the proper composition. Particularly is this true when large quantities of milk of the Channel Islands breeds is received at the condensary.

After the condensing process is completed, the condensed milk is analyzed and, if found to deviate from the standard desired by the factory, the composition is adjusted by the addition of the necessary ingredients. In the making of sweetened condensed milks, extreme care must be taken to standardize the normal milk at the hot well, as it is not a simple procedure to restandardize this type of milk after condensing because of the methods necessarily employed in handling the finished product.

Cooling Condensed Milks. After condensing reaches the proper point, the product is cooled. The system used varies materially in the case of sweetened and unsweetened condensed milk. Unsweetened condensed milk may be cooled in coil vats, or over surface coolers. Sweetened condensed milk must be cooled quickly and with some agitation. If agitation is used it must be slow, and conducted in such a manner as to prevent the incorporation of air in the finished condensed milk. Due to the high lactose content of sweetened condensed milk and the danger of the sugar crystallizing from the condensing, extreme care must be taken.

After condensing and cooling, the condensed milk is placed in the packages in which it is marketed. Evaporated milk is homogenized, cooled, placed in cans and sterilized. After sterilization, the canned milk is placed in shaking machines to break the coagulated casein. The finished evaporated milk is generally held for a period at the factory to permit any defects to develop which may be due to bacterial fermentation or faulty methods of handling the product.

Uses of Condensed Milks. Unsweetened condensed milk can be used in the home in cooking for any purpose for which ordinary milk is used. This product is sold under the name of evaporated milk or unsweetened sterilized milk, and marketed in cans of various sizes. Sweetened condensed milk is used in cooking in the home in cases when the added sugar contained in the condensed milk does not interfere. A large number of recipes have been prepared for home cooking, using both evaporated and sweetened condensed milk. Condensed milk, especially condensed skim milk, is used in large quantities by bakers, and candy and ice-cream manufacturers. The quantity used for these purposes far exceeds that used in the home.

Defects in Condensed Milks. The manufacturer of condensed milks must continually guard against a number of defects which may occur in the finished product. Though there are some defects common to both unsweetened and sweetened condensed milk, there are many other defects which are characteristic of but one or the other.

The most serious defects of unsweetened condensed milk are those which occur in the canned or evaporated milk. These defects are largely due to improper sterilization or leaky cans.

Bacterial fermentations are responsible for such defects as sour or curdled evaporated milk, the formation of gas, and a rancid or fishy flavor in evaporated milk. Still another defect which may occur in evaporated milk is the churning or separation of the milk fat.

The most common defect in sweetened condensed milk, common both to bulk and canned condensed, is the crystallization of sugar which causes the sandy or gritty product. This condition is due to the crystallization of lactose. There are a few defects which occur in sweetened condensed milk due to the growth of microörganisms. Such defects as a gassy and cheesy condition in sweetened condensed milk have been shown to be due to specific yeasts and bacteria. Certain molds have been shown to cause the formation of small buttons on the surface of sweetened condensed milk.

Marketing Condensed Milks. In general, condensed milks are sold either in bulk containers or in hermetically sealed tins. Such condensed products as plain condensed whole or skim milk, superheated condensed whole or skim milk, and condensed sweet-cream buttermilk are more frequently sold for use in the preparation of human foods. They are transported from the processor to the user in containers of various sizes. The 10-gallon milk can and the common 50-pound lard tin are the containers most frequently used for bulk shipments. When sold in bulk form, the sweetened condensed milk is placed either in tins, clean, wooden barrels, or steel drums. Condensed buttermilk and semisolid buttermilk when prepared from sour-cream buttermilk seldom, if ever, are used for human food but primarily for animal feed. These products are more commonly sold in kegs or barrels.

Sweetened condensed milk is packed in hermetically sealed tins for home and industrial use. The common tin for home use contains 14 or 15 ounces while the gallon or 10-pound tin is popular for industrial users including restaurants, hotels, hospitals, and institutions. The 14- or 15-ounce tins are packed 48 to the case for wholesale distribution while the 1-gallon or 10-pound tins are packed 4 to the case.

Evaporated milk, as previously indicated, is practically always packed in tins. Two sizes of cans, 6-ounce or 14.5-ounce, are commonly packed for home use. A 1-gallon-, or No. 10 tin and a "confectioner's-size" can (515 by 805) are packed for industrial use. The 6-ounce tins are packed 96 to the case while the 14.5-ounce tins are packed 48 to the case for wholesale distribution. The gallon and "confectioner's-size" cans are packed 6 to the case for industrial distribution.

A summary of the above statements is presented in the table on this page which includes also the weight of the containers and product as well as the total weight.

CHARACTERISTICS OF SOME CONCENTRATED MILK CONTAINERS[1]

Product and container designation	Weight of container, pounds	Weight of product as usually packed, pounds	Total weight, pounds
Sweetened condensed milk:			
Case: 48 14-oz. cans	9¾	42	51¾
Case: 48 15-oz. cans	9¾	45	54¾
Case: 4 1-gal. cans	10	45	55
30-gal. barrel	50	325	375
50-gal. barrel	72	615	687
Sweetened condensed skim milk:			
30-gal. barrel	50	325	375
50-gal. barrel	72	625	697
Evaporated milk:			
Case: 96 6-oz. cans	9	36	45
Case: 48 14½ oz. cans	8	43½	51½
Case: 6 #10 cans (603 × 700)	4¼	40½	44¾
Case: 6 confectioner's-size cans (515 × 805)	6½	48	54½
Plain condensed whole milk (total solids, 36%):			
10-gal. can	30	92	122
Plain condensed skim milk (total solids, 27%):			
10-gal. can	30	94	124

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[1] From Agricultural Research Administration, Bureau of Dairy Industry, U.S. Department of Agriculture, BDIM-inf-13, rev., November, 1946.

Canned milk or case goods are sold directly to wholesale grocery jobbers, who supply the retail stores. Larger retail stores are able to buy canned condensed milk, in the quantities required, directly from the condensary.

Bulk condensed milks are sold, more frequently, direct from the condensary to the baker, the candy maker, or the ice-cream manufacturer. Relatively small quantities of bulk condensed milk are shipped to some of the larger cities, where brokers sell it on the open markets.

DRY MILK

The preservation of milk in the dry form is by no means new. In a new translation of the travels of Marco Polo, referring to various customs of the Tartars in 1298, Marco Polo says:

> When the Service, that is, the Military Service, is distant, they carry but little with them. They make a provision of milk thickened and dried to a state of paste, which is prepared in the following manner. They boil the milk and skim off the rich or creamy part as it rises to the top, put it into a separate vessel as butter, for so long as that remains in, the milk will not become hard. The latter is then exposed to the sun until it dries. On going into the service, they carry with them about 10 pounds for each man and of this one-half pound is put every morning in a leathern bottle with as much water as is thought necessary. By their motion in riding, the contents are violently shaken and a thin porridge is produced, on which they make their dinner.

Dry milk was first manufactured commercially by Grimwade of England in 1855. It was not until 1883 that an attempt was made to manufacture dry milk in America and this was in the form of malted milk, a combination of whole-milk powder and the extract of malt. In 1872, Percy of New York City applied for a patent which embraced the idea of atomizing fluids into heated air. An improvement in the process was covered later by a patent secured by Stauf, of Germany, in 1901. The Stauf patent was purchased by the Merrill-Soule Company of Syracuse, New York. This patent expired in 1918 and since that date other companies have made use of the principles involved.

Methods of Manufacturing Dry Milk. One of the first methods employed in the drying of milk commercially was that known as the "Dough Process." This process consists of condensing the milk in a vacuum pan to a low concentration, after which the condensed milk is placed in trays in a drying chamber. After the product is dried, it is ground to a fine powder. The process is still used in a few isolated cases. The modern methods of drying milk, however, are known in a general way as the spray and the drum processes of drying.

The Spray Process. There are several methods now employed in the drying of milk by the spray process. Although the processes differ in some respects from one another, each makes use of the same general principles. Each method requires a large drying chamber, into which hot air is blown at a high velocity. A part of the water of the milk generally is removed previously by means of a vacuum pan. The condensed milk is then sprayed or atomized into the hot chamber where the finely divided milk particles are dried as they fall to the bottom. A portion of the very fine particles may drift with the outgoing air and for this reason various means have been provided to catch this portion of the dried milk which might otherwise be lost. The air may be filtered through fine meshed screens or cloth, or it may be washed free of powder with incoming milk, according to the process used.

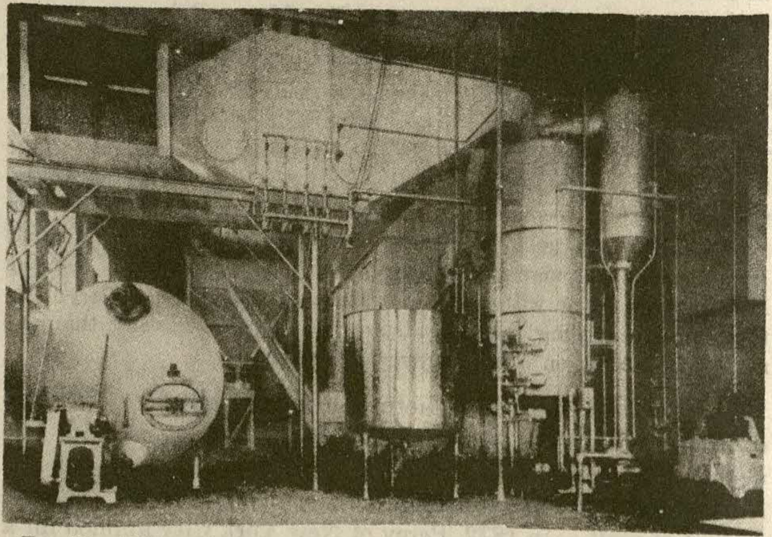


FIG. 82. Milk-condensing and milk-drying plant. Milk for the spray drier is first condensed. It is then sprayed in a fine mist into the hot chamber of the drier. The view above pictures the milk storage tank at the left, the hot well at the right center, the vacuum pan just right of the hot well; the pump used to pump the condensed milk under pressure to the drier stands at the extreme right. The milk-drying chamber is installed back of and above the vacuum pan and hot well. (*Courtesy of C. E. Rogers Company.*)

After the dried milk has fallen to the floor of the drying chamber, it is removed automatically either by means of mechanical devices or by suction. If no means are provided for removing the powder as it is formed in the drying chamber, the operator removes it by means of a scoop shovel at the completion of the day's operations. After being removed from the drying chamber, the dried milk is placed in various types of containers in which it is sold on the market.

Dry milk for human consumption, and for home or institution, may be placed in hermetically sealed tins. Products with a high fat content, such as whole milk or cream, are packed in cans containing an inert gas, such as nitrogen or carbon dioxide. The gas is introduced by placing the container holding the product under partial vacuum for a few seconds to remove the air and then replacing the air in the container with the inert gas on releasing the vacuum. The can is then sealed. Workers at the University of Minnesota have developed a method whereby the product may be dried in a closed system in the presence of an inert gas with the idea of eliminating the gassing procedure described above.

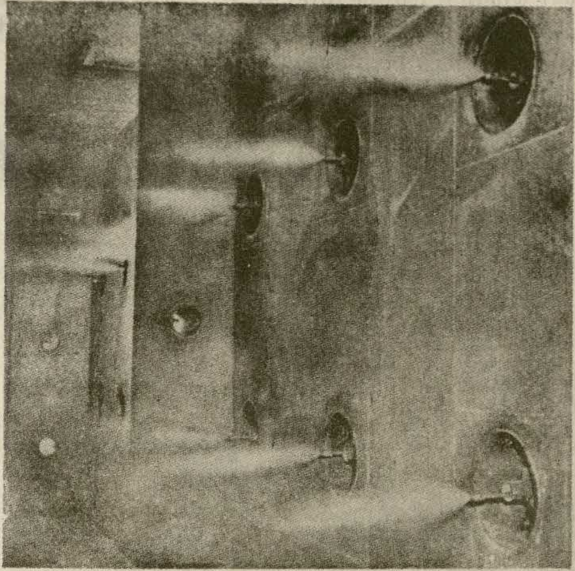


FIG. 83. Inside view of a spray drier. The milk is sprayed through nozzles in a fine mist into a chamber where there is a circulation of hot air. The jets or nozzles are shown as the milk is sprayed into the drier. (*Courtesy of Rochester Dairy Cooperative.*)

It should be stated further that it is deemed advisable to cool high-fat products as promptly as possible after the product leaves the drying chamber. This has been accomplished in various ways by passing currents of cold air over the powder. A simple method is to convey the hot powder from the drier to a coil vat. By discharging the hot, dry milk into the vat, while the cooling coil is in operation, the dry milk is worked to the end of the vat where it can be dropped by gravity to a suitable conveyor and then to a sifting machine where it is passed through a fine-mesh silk screen before packing.

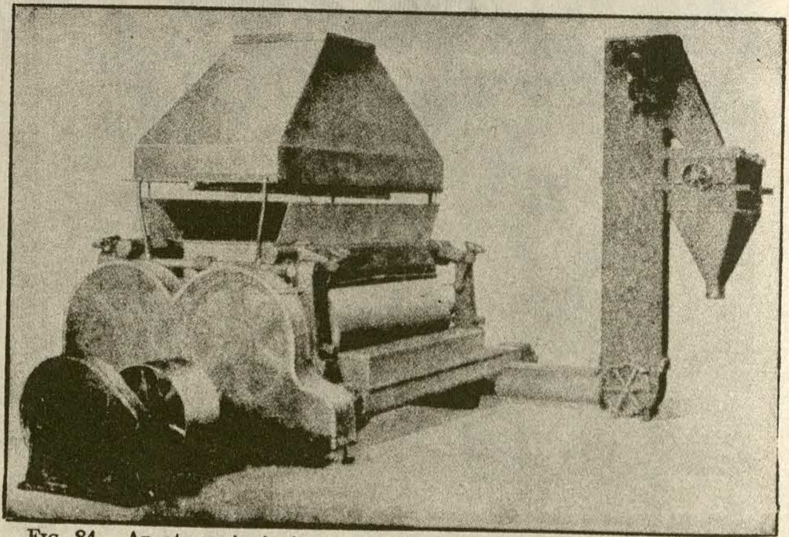


FIG. 84. An atmospheric-drum milk drier. Machines of this type are frequently used to dry sour-cream buttermilk used for stock feeding, and sweet-cream buttermilk and skim milk used for human consumption. The machine illustrated is a two-roll type. In addition to the rollers, a conveyor is shown at the side of the roll, and at the right is shown the flaker or mill where the dried milk is ground. (*Courtesy of Buffalo Foundry Company.*)

The Drum Process. The essential feature of this process is a slowly revolving drum heated to a high temperature from the inside with steam under pressure. The product to be dried either is allowed to flow onto the roller in a thin layer or is sprayed on the roller. There are two general types of drum driers on the market, generally termed "atmospheric-drum driers" and "vacuum-drum driers." The dried milk prepared by the drum process is commonly referred to on the market as "hot-roller process" dried milk. The quality of dry milk produced by the two drum processes depends largely upon the type of milk used, and the temperature to which the milk is subjected during drying. The greatest heat is used in connection with the atmospheric-drum process.

The atmospheric-drum process is used most commonly in the preparation of dried sour-cream buttermilk and dried skim milk. In sections of the United States where sweet cream is churned in butter making, the practice of drying sweet-cream buttermilk by the atmospheric-drum process is used in many creameries where sufficient amounts of the product are available. The general opinion prevails in many quarters that dry milk made by the atmospheric-drum process is of an inferior grade. This opinion is due, mainly, to the fact that so much low-grade material is prepared by this method from sour buttermilk and surplus skim milk. The process is also used for preparing dry whole milk, dry skim milk (non-fat dry-milk solids) and dry sweet-cream buttermilk used for human consumption, and when proper care is taken an excellent grade of product results. The solubility of these is about 60 to 70 per cent of that made by the spray process.

The vacuum-drum driers are used to a limited extent for drying whole milk.

Atmospheric-drum Process. The atmospheric-drum process of drying skim milk and buttermilk generally consists of two large, steam-heated, horizontal, steel, rotating drums or cylinders placed side by side. Since the milk during the drying process is continually under atmospheric conditions, the term "atmospheric" drum has been applied generally to driers of this type. Skim milk or buttermilk for drying is allowed to flow on or between the drums from a milk-supply tank suspended above the drier or else sprayed upon the drums by special devices. The milk forms in a thin layer over the surface of the drier and quickly dries, the vapors being removed from the immediate vicinity by means of a large vapor stack which leads to the outdoors. The dried milk is removed from the surface of the drums as they revolve by means of sharp, close-fitting blades which extend along the sides of the drum. The dried milk comes from the roller in a thin sheet which is easily broken into flakes as it falls into a trough along the side of each drum. From the trough the dried flakes are worked mechanically toward the end of the drier, where they are sacked. In this condition the dried milk is sold as milk flakes. More often, however, the flakes are ground as they reach the end of the drier into a powder which is finely milled and placed either in sacks of 100 pounds each, or barrels of 200 pounds each. Generally, dried milk intended for animal feed is ground and placed in sacks while that intended for human consumption is finely ground, milled, and placed in barrels. The milling process is frequently carried on at some central point, as a matter of economy.

Vacuum-drum Process. Milk dried under atmospheric pressure requires an exceedingly high temperature in the drum if thorough drying is to be accomplished. The vacuum drum consists of a machine somewhat similar to the atmospheric drier. It differs, however, in that the drums are encased and revolve in an atmosphere of reduced pressure due to a partial vacuum which is maintained. The milk is applied to the drum in several different ways. The drum may dip into the milk, or the milk may be sprayed onto the drum at certain points, generally at the bottom. In all types of driers using this process, the milk is subjected to a lower drying temperature than is used in the case of the atmospheric drums. It is the reduced heat used in such machines which probably accounts for better solubility of the dried milk that results, as compared with the dried milk prepared on the atmospheric drums.

Grinding and Milling. Theoretically, spray-process powders are ready for the final package immediately after the drying process. As an extra precaution, especially against lumps of caked milk occurring in the finished product, the spray powder is often passed through a bolting machine before being placed in the containers in which it is marketed. Milling of the powder, however, is not essential. In the case of dried milk made by the drum process, the product is passed through grinding and bolting machines and milled before being placed in the final container. Frequently, drum-process milk is not ground or bolted but the flakes of dried milk are placed in sacks and sold as "dried flakes."

Grading and Standardizing. To meet the market demand, it is essential that dealers in dried milk assemble large quantities of various grades for distribution. Accordingly, much of the dry milk produced is assembled in central warehouses and graded according to its color, presence of foreign matter, and composition. All first-grade products are then mixed in milling machines, care being taken to produce a finished article of a uniform composition, particularly a uniform fat content.

Types of Dry Milk. The terms applied on the market to the various types of dried milk are intended to indicate the fat content of the dry milk, the nature of the milk from which the product was made, and the drying process used in the manufacture. Whole milk, cream, skim milk, buttermilk, and whey are dried commercially. The drying may be accomplished by the spray process, or the hot-roller or drum process.

Dry Whole Milk. Dry whole milk or whole-milk powder is made largely by the spray process. The term implies that the powder was made from whole milk which contained a normal percentage of milk fat.

Dry Cream. "Dry cream" or "cream powder" implies that the moisture of cream has been removed almost entirely by the drying process. The spray process of drying is used in its manufacture.

Dry Skim Milk (Non-fat Dry-milk Solids or Defatted Milk Solids). The spray and hot-roller or drum processes are used in drying skim milk. Since there is a difference, particularly in the properties of the milks prepared by the two processes, it is the common practice on the market to indicate the process used when referring to dry skim milk. The terms "spray-process skim-milk powder," or "spray process non-fat dry-milk solids," or "dry skim milk, spray process," or "non-fat dry-milk solids, spray process," are used to designate dry skim milk made by the spray process. The terms "hot-roller" or "drum-process non-fat dry-milk solids" or "non-fat dry-milk solids, hot-roller or drum process" are used to designate dry skim milk made by the hot-roller or drum process.

Dry Buttermilk. Dry buttermilk is more frequently made by the hot-roller or drum process. The term "dry buttermilk" or "buttermilk powder" is commonly understood to mean buttermilk dried by the hot-roller or drum process. Buttermilk churned from sweet cream is frequently dried by the spray process. This is designated as "spray-process sweet-cream buttermilk powder."

Dry Whey. Dry whey is prepared either by the drum or spray process. Because of the anhydrous lactose present it is necessary to introduce some process to encourage lactose crystallization before drying. Many patents have been granted to accomplish this purpose. In general these patents include methods of inducing crystallization by concentrating the whey; drying the whey and permitting it to absorb water to force crystallization before drying is completed; and seeding with beta-lactose at 200°F. (93.33°C.) and holding at this temperature while the lactose crystallizes and while drying.

Dry Ice-cream Mix or Base. Efforts have been made for more than 25 years to prepare a suitable, dry ice-cream mix or to dry the solids of milk in the proper portion for use by the ice-cream manufacturer. Considerable progress was made with dry ice-cream mix during the Second World War when the U.S. Army Quartermaster Corps bought several millions of pounds for use overseas. Following the war, commercial manufacturers made a dry ice-cream mix which included all the ingredients for a vanilla ice cream for distribution at home and abroad. A "base mix," consisting of the solids of milk in proper ratio, is prepared for those who wish a product to which they may add sugar, stabilizer, and flavoring in amounts they prefer.

Composition of Dry Milk. According to a ruling set forth by the U.S. Department of Agriculture, dried milk made from whole milk must contain not less than 26 per cent of milk fat, and the moisture content must not exceed 5 per cent. In addition, the Department has ruled that non-fat dry-milk solids (dry skim milk) shall not contain more than 5 per cent of moisture. The dry-milk manufacturer, therefore, takes every precaution to insure a product which will conform with the United States standards.

The composition of dry milk varies according to the composition of the milk from which it is made. Due to elimination of most of the water in the process of drying, the other milk constituents are increased in about the same proportion. Some difficulty is experienced in making the determination of moisture in dry milks, owing to their colloidal nature. Other constituents are quite readily determined by the standard methods. It is not possible to set forth an entirely satisfactory statement concerning the composition of the various dry milks, because comparatively few analyses have been published. The authors of the book "Fundamentals of Dairy Science" present a number of analyses made by several workers. This material is presented in Table XIV.

Properties of Dry Milk. The properties of dry milk are due largely to the constituents of the milk from which it is made. These properties have an important influence on the uses to which dried milk may be put in the dairy and other industries. If it is to be remixed with water to make a reconstructed milk, it is important that the user be aware of the extent to which the various types of dry milk may be used for this purpose. If dried milk products are to be of value in the various food industries, they must possess good keeping qualities. The relation of certain properties to the keeping quality is, therefore, important. The influence of heat on the constituents of milk was previously discussed. It is to be expected that dry milk will possess certain properties which can be linked directly with the influence of heat on such constituents of milk as casein, albumin, calcium salts, and lactose.

TABLE XIV. COMPOSITION OF DRY MILK AND MILK PRODUCTS[1]

Dry product	Water, percentage	Protein, percentage	Fat, percentage	Lactose, percentage	Ash, percentage	Total milk solids, percentage
Whole milk...	4.00	27.20	26.00	36.80	6.00	96.00
Cream........	0.66	13.42	65.15	17.86	2.91	99.34
Skim milk....	4.00	37.40	1.00	49.20	8.40	96.00
Sour buttermilk........	1.93	38.74	5.87	39.91	7.68	98.07

[1] "Fundamentals of Dairy Science," 2d ed., Reinhold Publishing Corp., New York. Table by Wright, Research Laboratories, Bureau of Dairy Industry, Washington, D.C.

Solubility. It is frequently desired to prepare a reconstructed milk from dry milk and water or to remix water with the dry milk. The degree to which the dry milk will disperse in water is commonly referred to as its "solubility." Spray and vacuum-drum process products readily disperse in water and acquire many of the properties of the original milk from which they were prepared. If reconstructed milk prepared from such dry milk be examined, it will be observed that practically no sediment is formed after setting or centrifuging. In addition, the reconstructed milk will pass through a filter paper as will normal milk.

Dried milk made by the atmospheric-drum process, however, disperses in water more slowly and less completely. When reconstructed with water and allowed to stand, a relatively large amount of sediment settles to the bottom, and, on filtering the mixture, a large proportion, relatively, remains on the filter paper. In general, it is conceded that dry milk made by the spray process is about 99 per cent soluble, that made by the vacuum-drum process soluble nearly to this extent, while that made by the atmospheric drum is from 60 to 70 per cent soluble.

Color. The color of dry milk is influenced by the carotene content of the original milk. If the milk from which the dry milk is made is rich in carotene, the resulting product will possess a darker yellow color than that made from milk lacking carotene. Dried milks subjected to high heat, such as used in the atmospheric-drum process of drying, possess a darker color than those made under conditions where the milk is not subjected to such high temperatures, as in the case of those made by the spray or the vacuum-drum processes. When milk of a relatively high acidity is dried, the resulting material appears dark in color. Dry, sour-cream buttermilk, which is dried almost entirely by the atmospheric-drum process, is very dark in color.

Hygroscopic Properties. All dried milk possesses the property of taking up moisture from the air unless sealed in air-tight, moisture-proof containers. The keeping quality of dry milk is endangered by this property if proper precautions are not observed. In addition, certain physical changes take place which cause the dry milk to form very hard lumps if it is permitted to take up moisture from the air.

Taste. Dry whole milk has a pleasant taste, somewhat sweetish and with a slight suggestion of heated milk. Non-fat dry-milk solids have a similar although less pronounced taste. Dry buttermilk varies greatly in taste, that made from sweet-cream buttermilk having a rather more agreeable taste than dry skim milk, while that made from sour buttermilk has an acid taste and, usually, as a result of the method of manufacture, a decidedly "cooked" taste.

The taste of heated milk is presumably due to the effect of the heat upon the protein and sugar of the milk. When any of these dry products are reconstituted, the taste of heated milk persists and is a factor limiting the use of dry-milk products in ice-cream manufacture.

Action of Rennet on Reconstituted Dry Milk. The action of rennet on reconstituted dry milk varies with the conditions of manufacture and the method of drying the milk. Dry milk from the spray process, when reconstituted, may be coagulated by rennet, although the action is not the same as with normal milk. The curd is frequently very soft, flocculent, and uneven. This condition, however, is improved and the curd more nearly like that of normal milk when the temperature of preheating the fluid milk preceding condensing and drying is not above 145°F. (62.78°C.). There is also some evidence that the temperature at which the milk is dried may be an important factor affecting the firmness of the clot formed with rennet coagulation. The temperature used in drying milk by the drum process is relatively high, and the properties of the milk are affected to such an extent that rennet has slight effect upon the reconstituted product.

The above facts have a very practical application when consideration is given to the possible use of non-fat dry-milk solids (dry skim milk) in the preparation of starter, cultured buttermilk, Cottage cheese, standardizing the solids of skim milk for Cottage cheese, and in raising the solids-not-fat of milk in making Cheddar or other varieties of cheese.

Use of Dry Milk. Dry milk was first produced as infant food. Its use has spread into every industry manufacturing food products in which normal milk is used. It is used in the baking industry, in candy and ice-cream manufacture, and prepared pancake and biscuit flours. The meat industry makes use of dried skim milk and sweet-cream buttermilk in the preparation of certain types of sausage. In the kitchen of the home or restaurant either dried whole or skim milk is frequently used because it is convenient. It was introduced into thousands of homes in the United States and elsewhere during the Second World War. Housewives have learned that dry milk may give satisfactory results in the preparation of almost any dish in which fluid milk was used previously. The armed forces of the nations at war found dry milk to be a valuable food product with good keeping quality and compactness.

Dried whole milk, skim milk (non-fat dry-milk solids), or buttermilk makes excellent feed for calves, pigs, and chickens. The dry-milk products used for animal food ordinarily are of a lower grade, that is, they are not quite fine enough in quality for human food. The lower grades may be such largely because the raw products may not have been carefully chosen or the machinery or processing methods may not have met the strict standards set up for the best grade of dry products.

Malted Milk. Malted milk is prepared by the drying of a mixture consisting essentially of whole milk combined with the fluid separated from a mash of ground barley malt and wheat flour. It must contain not less than 7.5 per cent fat and not more than 3.5 per cent moisture. It is used widely as a delicious food especially when mixed with fluid milk or ice cream.

Defects in Dry Milk. The defects in dry milk of most importance are those which occur in that intended for human consumption. The most serious defects are those affecting the flavor of the dried milk, its physical makeup, cleanliness, and color.

The most common flavor defect in dry milk made from whole milk is the development of tallowiness. This flavor is doubtless due to the oxidation of milk fat.

Non-fat dry-milk solids (dry skim milk) seldom, if ever, has a tallowy flavor but may develop a characteristic stale flavor. Dry sweet-cream buttermilk may develop this stale flavor in the course of a few weeks if stored at room, or higher, temperature.

Still another flavor, common only in dried milk containing milk fat, is rancidity. This defect appears to be due to the hydrolysis of milk fat, resulting in the liberation of butyric and other fatty acids.

Other defects in flavor may occur in dry milk in general. The most easily detected is a stale, or old and musty, flavor which develops after it is held in storage for a period, particularly when any increase in the moisture content takes place.

If proper methods are employed in the drying process and the finished product is permitted to retain a relatively high percentage of moisture (above 5 per cent), it will develop a lumpy condition. In extreme conditions, the physical appearance will become altered and the lumps be exceedingly large and very hard. So hard will they often become, that they can be broken up into pieces only with a hammer. The cleanliness of dry milk is exceedingly important if it is to be used for human consumption. Foreign material of any nature will render it unfit for use other than for animal feeding.

The color of dry milk is influenced by many factors, many of which are unsolved. That which is made from whole milk should be clear and uniform and no dark specks should be visible. The same thing applies to others intended for human consumption. One of the common color defects of dry milk made by the hot-roller or drum process is the appearance of dark-brown specks of burnt milk. Such a condition often indicates unclean conditions in the plant.

The fresh flavor characteristics of any and all of the dried-milk products may be preserved for many months if they have a low-moisture content, not above 2 per cent, and if the product is held under refrigeration. These two factors, moisture content and temperature of storage, are extremely important in determining the keeping qualities of dry milks. These facts are not too well appreciated either by the manufacturer or the user of these products.

Marketing of Dry Milk. Dry milk is marketed in several types of containers for home consumption and commercial users. The common container for commercial use is a wooden barrel lined with a tough, durable, paraffined or crumpled paper. Metal containers, fiber drums, and paper sacks also are used. These containers are packed to contain from 25 to 200 pounds. A limited amount of dry whole milk is packed in 1- and 5-pound hermetically sealed tins. When cans of these sizes are used, the oxygen is removed from the dry milk and replaced with nitrogen or carbon dioxide. These containers are intended primarily for home or institutional use. A sealed, paper container, designed to hold sufficient dry whole milk to prepare 1 or 2 quarts of reconstituted milk, is available for the home. Efforts to place non-fat dry-milk solids (dry skim milk) in consumer packages so far has proven too costly. This form of dry milk is packed, however, in sealed tins containing 4.5 pounds. These may eventually be conveniently available to the home user.

Dry ice-cream mix is packed for bulk users in containers similar to those mentioned above. It is packed also in small containers holding about 5 ounces, or sufficient to prepare 1 quart of ice cream in the home.

Dry milk prepared by the drum process is packed in bulk containers almost exclusively, except for a small amount in consumer packages. When dry milk, made by the drum or spray process, is prepared for animal feed it is frequently packed in burlap bags or common feed sacks. Burlap bags are lined with crinkled or paraffined paper.

A great deal of progress has been made by the manufacturers of dry milk in setting up definite market grades through the American Dry Milk Institute, Inc. Dry milk is classified into two groups namely, (1) human food, and (2) animal feed. Dry milk for human food to be sold in bulk form is then classified into two grades, extra and standard grades. Dry whole milk placed in gas-packed, hermetically sealed tins is given a premium or extra grade. The specifications for dry milks are set forth in the Appendix.

Reconstituting Dry Milk. When dry milk is to be reconstituted it is only necessary to incorporate water. The required amount of the dry milk is added to a given quantity of lukewarm water and immediately stirred until the dry milk has been completely dispersed. In the home, this can be done in several ways. Water may be placed in a mixing bowl and, after adding the dry milk, an ordinary egg beater may be used. The electric mixer is an excellent device for reconstituting. A simple method is to place the desired amount of water in a common fruit jar, add the dry milk, fix a jar rubber in place, screw on the cover, and proceed to shake by hand.

Hotels, restaurants, and institutions may find the ordinary milk can a suitable receptacle for use in reconstituting. A milk- or cream- stirring rod may be used for agitating. Mechanical stirrers are available, however, and are quite suitable for the purpose.

In food factories, where larger volumes are reconstituted, other means must be found. It is possible to place the water in a vat on which may be mounted an electric mixer for agitation.

By feeding water and the dry milk together to a centrifugal pump, the job can be accomplished in short order. This may require the construction of special equipment, but it is an effective procedure. Still another suggestion is to place the water and dry milk in a vat and draw the mixture from the bottom into a centrifugal pump with the discharge leading back into the vat.

By recirculating the mixture from vat to pump and back to the vat, the milk may be dispersed with little effort in large volume.

MICROBIOLOGY OF CONDENSED AND DRY MILK

The types of microörganisms which will be present in condensed or dry milk will depend upon the flora of the original milk, the extent and kind of contamination in processing, and the relative resistance of the various types present to the processes of condensing or drying.

In the condensing of milk by the vacuum-pan method, the milk is subjected for a short period of time to temperatures ranging from 167 to 212°F. (75 to 100°C.) in the forewarming process. This results in a marked reduction in the total number of microörganisms. During the evaporation in the vacuum pan, the milk is exposed for some time at 130 to 145°F. (54.44 to 62.78°C.). This ordinarily leads to a further destruction of the thermolabile types of organisms. However, there is some evidence to indicate that certain bacteria actually may develop during the condensing process. When superheating is employed at 180°F. (82.22°C.) or higher, a further decrease in numbers of bacteria will ordinarily follow. There will appear in the concentrated product a variable number of organisms, at times a considerable number. Steps must then be taken to hold these organisms in check if the product is to possess a good keeping quality. Further recontamination of the condensed milks must be prevented as far as possible after the heat treatment.

Effect of Low Water Content, and Concentration of Solids. In the case of the regular sweetened condensed milk, the water content is usually somewhere in the neighborhood of 25 per cent, which, with the concentration of the milk solids, does not provide a very satisfactory substratum for bacterial development, but which, nevertheless, will not prohibit the growth of some types. To overcome this situation, cane sugar is added so that the final product contains about 40 per cent of cane sugar. This, together with about 30 to 35 per cent of milk solids, competes for the small amount of water. Thus a thick syrup is formed which tends to draw water from the cells of the microörganisms by osmotic pressure with the result that the metabolism of the cell is disturbed to such an extent that it cannot grow and develop normally. For this reason, there is seldom any growth of microorganisms in sweetened condensed milk, and when it is sealed in a tight can its keeping quality is good.

In the case of the unsweetened type of condensed milk, which is usually called evaporated, the moisture is somewhat higher, perhaps up to 75 per cent. This product would be very susceptible to the growth of microörganisms. For this reason, it is necessary to subject it to a heating process, usually at 240 to 245°F. (115.7 to 118.3°C.) for 15 minutes or more, in order that all the microörganisms may be destroyed. Evaporated milk owes its keeping quality to the freedom from living microörganisms.

Microörganisms in Dry Milk. In the case of dried milk, the process of desiccation is carried to the point where only a trace of water remains in the final product, usually less than 5 per cent. The numbers of microörganisms which will remain in the dry milk will depend upon the method of drying. Where the spray process is used, the temperature of the atomized particles of milk is never very high. Consequently, a sample of fresh powder produced by the spray process may contain thousands or even millions of bacteria per gram, as well as other types of organisms. With the drum process, the film of milk upon the revolving cylinder will reach a high temperature. As a result of this, the majority of organisms will be destroyed and only the most resistant forms will survive. Thus, the bacterial content of drum-dried milk will usually be a few thousand or much less per gram. Either type of dried milk may pick up contamination during drying, packing, or subsequent handling.

When the dried product is kept for a period of time, there is a tendency for some of the organisms to die, as it is a general rule in biology that if a cell is not growing, it is dying. With the small quantity of water left in the dried milk, there can be no growth, and, consequently, no deterioration of the product can occur because of the activity of microörganisms. Instead, the decrease in numbers continues throughout the life of the dry milk.

Defects Due to Microörganisms. There are certain defects which may appear in sweetened condensed milk as the result of the growth of certain bacteria and yeast-like organisms which are able to grow in such a concentrated material. Swelling of the package, due to the gas formation, abnormal thickening, and coagulation followed by protein decomposition may take place.

Hard, brownish lumps called "buttons" may develop because of the growth of certain molds, such as *Aspergillus repens*.

The evaporated milk, if improperly sterilized or carelessly sealed in the cans, may develop bitter or fishy flavors due to the growth of bacteria. Gas production may also take place sufficient to cause the bulging of the can.

No specific defects of dried milk can be attributed to microörganisms until the product is reconstituted to resemble normal milk by the addition of water. The chances that condensed or dried milks may transmit disease-producing bacteria are rather remote. Pasteurization of the milk before concentration will reduce this possibility to a minimum.

MILK BY-PRODUCTS

Market milk and market cream utilize about 35 to 40 per cent of the milk produced in the United States. The remainder is used in the manufacture of such dairy products as butter, cheese, condensed milk, dry milk, and ice cream. A relatively small quantity is used in the feeding of farm animals, principally the dairy calves. In the separation of milk for market cream and in the manufacture of butter and cheese, there become available large quantities of skim milk, buttermilk, and whey. These three products are the by-products of the dairy industry. The larger part of the dairy by-products available in the United States is, at present, used for animal feeding. There are indications that this practice will not continue indefinitely. In the future, the use of dairy by-products for human food is certain to increase. They offer also a vast reservoir of material for industrial uses.

Skim Milk as a By-product. On the average, 85 pounds of skim milk are available from each 100 pounds of milk separated. The question of the utilization of this skim milk arises whenever milk is separated to obtain cream for market purposes or butter making. Some skim milk is usually available in city milk-distributing plants, but a place is found for the relatively small amounts by using it for Cottage cheese and other purposes. The real problem of using skim milk to advantage arises in those localities where the extensive manufacture of butter results in enormous quantities of skim milk. The essential difference between skim milk and whole milk is the fat content. One of the authors found the average fat content of 93 samples of skim milk from farm separators to be 0.07 per cent as determined by the modified Roese-Gottlieb (Mojonnier) method. The same samples averaged 0.02 per cent fat by the Babcock method, using the skim-milk bottle. The lower reading from the Babcock method is in accordance with the experience of others. This method when applied to skim milk gives results which are too low. In protein, skim milk varies between 3.4 and 3.8 per cent; the sugar is less variable, averaging between 4.9 and 5.0 per cent; the mineral content is approximately 0.8 per cent.

Skim Milk as an Animal Feed. On farms marketing cream or butter, a portion of the skim milk, as a rule, is used for raising the calves necessary to maintain the dairy herd. The remainder is largely used for feeding pigs and poultry. The remarkable efficiency of skim milk as a supplement to corn and cereals for growing pigs is well known. Poultry, also, make excellent use of skim milk. The special value of dairy by-products for these purposes is due largely to the quality of the proteins. Cereal proteins are not very efficient, while milk proteins supply what is lacking in the grain proteins. Under conditions of cheap human food it is conceded that skim milk, buttermilk, and whey can in many localities be used with advantage as animal feed. There is a limit, however, to the amount that can be used with economy in this way. Economic reasons, for example the lack of sufficient grain, often stand in the way of the farmer's increasing the number of pigs to a point where the skim milk available can be fed with advantage. In the state of Minnesota, for example, after allowing for all the skim milk the calves, pigs, and poultry in the state can use to advantage, at least 1,500,000,000 pounds of skim milk are available for industrial purposes.

Skim Milk for Human Food. The value of skim milk as a human food has not been generally recognized in America until recently. Meat has been the chief source of animal protein in the American diet. In the by-products of the dairy industry there are nearly as many pounds of protein as in all the beef, pork, and mutton consumed in the United States Milk protein can largely replace meat protein in the human diet, as is seen by the small per capita consumption of meat and the high consumption of milk solids in the form of milk and cheese in Europe. When skim milk is fed to the pig, only about 13 to 16 per cent of the protein content is returned in the form of human food. The 84 per cent of the protein so wasted could have been used for human food. Whether skim milk shall serve as animal food primarily or as a human food is largely a problem of economics. In Denmark, at present, about one-half of the skim milk produced is utilized in the diet of the human, the other half being fed to the pig. In Germany, however, very little skim milk is fed to livestock; practically all of it produced serves as a source of animal protein in the human diet.

Other Uses of Skim Milk. As pointed out, the largest use of skim milk at present is as an animal food. This is likely to decrease rather than increase as other and more economical means of using larger portions of the product are coming into use. It is probable, from European experience, that the future will see more skim milk, in the form of cheeses of various types, used as human food. A hundred pounds of skim milk yields 15 pounds of Cottage cheese equal in value as human food to an equal weight of round steak. It is clear that, when food prices become higher in proportion to the income, the consumption of such products as Cottage cheese is certain to increase. At present, the chief products made from skim milk are condensed skim milk, dry skim milk, and casein.

The condensed product finds extensive use in the baking industry and in the manufacture of confectionery. Limited amounts are also used as a means of increasing the solids in ice-cream mixes. The dry product is also used by the baking industry in bread making, pie fillings, cookies, doughnuts, and similar bakery products. Under the lend-lease program, large quantities of dry skim milk have been shipped abroad to supplement the diet of our allies. Dry skim milk is further used in the preparation of ready-mixed pancake, cake, and doughnut flours. Certain infant foods are prepared which consist of modified dry skim milk. It is used by certain firms in the preparation of sausage, to which it contributes added food value and adhesive properties. So extensive are the possibilities of the use of dry skim milk in the prepared-food industries that it is inconceivable to what extent the product may be used in the future. In the manufacture of candies, such as chocolates, dry skim milk is extensively used. It is used, also, as is the condensed product, in increasing the milk solids-not-fat content of ice cream.

Skim milk is the most desirable product from which to manufacture casein. Attention has been previously brought to the uses of casein in the manufacture of casein plastics, its use in the textile and leather industry, as a glue, and in the manufacture of paper coating, casein fiber, paints, etc.

Buttermilk. The cream churned for butter averages about 30 per cent butter fat. For each 100 pounds of butter made, there are available, as a by-product, approximately 166 pounds of buttermilk. The composition and food value of buttermilk are essentially the same as those of skim milk. The fat content is somewhat higher, however, and in the case of buttermilk from sour cream, the sugar content is lower. In sour-cream buttermilk from 10 to 15 per cent of the original sugar has been changed into lactic acid through the activity of bacteria. The acid content expressed as lactic acid usually does not exceed 0.8 per cent but may reach 1.0 per cent if certain types of bacteria have taken part in the fermentation. Analyses by the authors of a large number of buttermilk samples from typical creameries showed a range in fat content from 0.1 to 0.6 per cent. The buttermilk from over 2,000 churnings made in a creamery operated under especially well-controlled conditions contained on the average slightly less than 0.20 per cent of fat, as shown by the regular Babcock test. In addition to the fat, typical buttermilk will contain about 90 per cent of water, 3.5 per cent protein, 4.4 per cent sugar, 0.6 per cent lactic acid, and 0.7 per cent ash.

At present, large quantities of buttermilk are practically wasted or at best are not used economically. A common practice in connection with the smaller creameries is to sell the buttermilk to someone who uses it for feeding swine. Fed in reasonable quantities, buttermilk is an excellent supplement to cereals and corn.

Commercial Products from Buttermilk. Due to its economical advantages, the practice of drying buttermilk is rapidly coming into use. The dry product proves to be especially valuable as a constituent in the ration for young chicks. It is also used with advantage in calf raising as a substitute for skim milk, where the whole milk is marketed. A small amount of buttermilk is used for the manufacture of casein. The quality of the casein, however, is not satisfactory and, for this reason, the use of buttermilk for this purpose is limited. A fairly large amount of buttermilk is condensed and, in this form, sold for animal-feeding purposes under various trade names. Recently, there has appeared on the market a good deal of condensed and dried buttermilk which are derived from the churning of sweet cream. These products have some especially desirable qualities and are used almost exclusively in connection with the preparation of human foods, including ice cream.

Whey. Whey is a by-product in the manufacture of cheese and casein. It is estimated that approximately 95 per cent of the available whey is a by-product of cheese manufacture. In the ordinary Cheddar process, the yield of cheese is about 10 pounds per 100 pounds of milk, leaving about 90 pounds of whey. In actual commercial practice it is generally estimated that 85 pounds of whey become available from each 100 pounds of milk used in cheese making.

The solids in true solution in milk largely pass into whey in the manufacture of cheese or casein. It is estimated that of the total solids in milk, 42 to 44 per cent are to be found in whey. These solids include over 90 per cent of the milk sugar and lactalbumin, a portion of the mineral matter and fat, as well as a very high percentage of the water-soluble vitamins of the original milk. The fat content is somewhat higher than in skim milk obtained from an efficiently operated centrifugal separator. The composition of typical cheese whey is: water, 93.4 per cent; fat, 0.35 per cent; protein, 0.85 per cent; milk sugar, 4.8 per cent; and ash, 0.6 per cent. The fat content may be reduced to approximately 0.10 per cent by centrifugal separation. The fat so recovered is used in the manufacture of butter, frequently termed "whey butter." The composition of casein whey differs from cheese whey chiefly in that it contains a higher percentage of ash, about 33 per cent.

Vast quantities of whey are produced in the manufacture of cheese in the United States. The common practice is for the farmer delivering milk to a cheese factory to take whey back to the farm in proportion to the milk delivered. It is used on the farm to supplement cereals and corn as a feed for swine and poultry. It is fed to a limited extent to calves. A relatively small proportion, about 25 per cent of the whey produced, is processed commercially. Large quantities, undoubtedly, are wasted at the present time.

Commercial Products from Whey. One of the first products to be made from cheese whey was whey cheese. The most common is Mysost, more commonly known as "Primost" in America. This cheese is made by boiling off the water of whey and concentrating the solids into a thick, pasty mass which can be poured into suitable forms. During the boiling process the coagulated albumin rises to the surface and may be removed for the preparation of Ricotta or Ziger.

The introduction of more modern methods of condensing and drying of milk and milk products has encouraged the development of products from whey which now have become important by-products. The chief obstacle confronting the development of this industry is the need to process large volumes of whey if the venture is to be profitable. Very early in the history of this industry a plain condensed whey was prepared for animal feed. Today whey is dried both for use as animal feed and for human consumption. It is dried either by the drum or spray process. When dried by the drum process it is usually combined with skim milk, buttermilk, or with finely dispersed cereals and used as animal feed. The spray-processed, dried whey may be used in prepared animal feeds or in human foods such as processed cheese, cheese spreads, prepared soups, ice cream, bakery goods, infant foods, and candies.

Fermentation products from whey have been explored sufficiently to indicate that they offer unusual possibilities. By fermentation with special cultures the riboflavin potency of the dry whey is increased as much as two hundredfold, or about twenty times that normally present. The product is used primarily to reinforce the vitamin content of prepared poultry and pig feeds. From the distillate of the fermented whey other profitable items such as butyl alcohol and acetone are prepared. A whey vinegar and wine represent other types of fermented products from whey.

A crude milk sugar is said to have been prepared from whey as early as 1628. Up until about 1880 milk sugar was made commercially only in Switzerland. Following this date factories were established in other sections of Europe and the United States.

The method of manufacture consists first of separating the fat from the whey by means of a high-speed centrifugal separator.

Albumin, which coagulates by heat, is then removed by boiling the whey after the addition of acetic acid. The whey is then placed in a vacuum pan and concentrated until it contains about 60 per cent solids. The concentrated whey is placed in tanks around which cold water is circulated. The milk sugar crystallizes and is removed by centrifuging. Refining is accomplished by dissolving the milk sugar in water with bone black and acetic acid. The liquid is boiled to get rid of still more albumin and the phosphates of milk. These are filtered from the liquid, which is then recondensed in the vacuum pans. The concentrated sugar is then dried and ground.

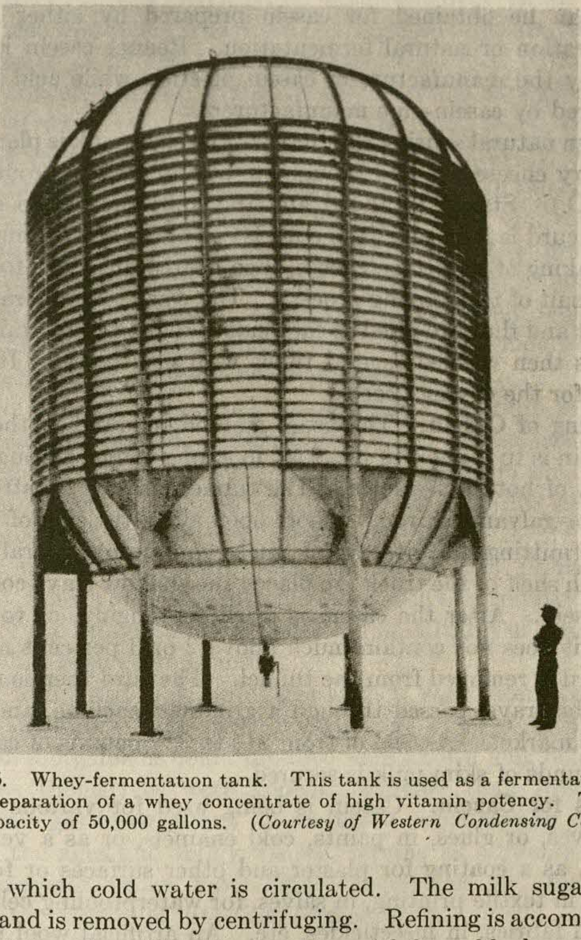


FIG. 85. Whey-fermentation tank. This tank is used as a fermentation tank in the preparation of a whey concentrate of high vitamin potency. The tank has a capacity of 50,000 gallons. (*Courtesy of Western Condensing Company.*)

Manufacture of Casein. The first step in the manufacture of commercial casein is the coagulation of the casein of skim milk either by natural lactic-acid fermentation, the addition of other acids, or by rennet. Casein prepared by rennet coagulation cannot be used for all purposes. It is darker in color, and often higher in fat, and generally does not bring the price on the market that can be obtained for casein prepared by either artificial acidification or natural fermentation. Rennet casein is largely used by the manufacture of casein plastics, while acid casein is preferred by casein-glue manufacturers.

When natural souring is practiced, the skim milk is placed in an ordinary cheese vat and brought to a temperature around 70°F. (21.1°C.). Starter is added and the milk allowed to set until a firm curd is formed. The curd is cut or broken up much as in the making of a Cottage cheese, then heated until it is toughened as a result of the cooking process. The whey is then drawn from the vat and the curd piled at each side and allowed to drain. The curd is then washed several times with cool water. It is then ready for the drying process.

Drying of Casein. The usual method followed in the drying of casein is to place it in trays set in a long tunnel through which a blast of hot air is blown. The tunnel may be constructed of wood or galvanized iron. Doors open along the side of the tunnel, permitting the entrance of trucks containing several shelves. On each shelf of the truck are placed the shallow trays containing the casein. After the casein is dried thoroughly, or to a point where it does not contain much above 2 or 3 per cent moisture, the curd is removed from the tunnel. The curd then is removed from the trays, passed through a grinding machine, and sacked for the market. A yield of from 2½ to 3½ pounds of casein per 100 pounds of skim milk is secured.

Uses for Casein. Casein is being used for various plastics, adhesives, or glues, in paints, cold enamels, or as a vehicle for paints, as a coating for plaster and other surfaces or for paper sizing, in textile printing, in salves, for waterproofing cellulose or protein fabrics, in insecticides, etc. An artificial wool prepared from casein in the form of fibers and threads has been receiving considerable attention in the United States and other countries. There are many possibilities for the utilization of casein that are still in the experimental stage.

FERMENTED MILK BEVERAGES

Whenever man has led a nomadic life, accompanied by herds of domestic animals, he has made extensive use of milk, or its products, for food. The earliest historical records speak of the use of fermented milk beverages as important items in the simple diet of these wandering tribesmen. The Bible contains a number of references as to the use and virtue of curdled milk. It is easy to conceive of the primitive conditions of sanitation and lack of refrigeration. The milk from the cow, sheep, goat, or mare was undoubtedly highly contaminated with many different microörganisms. The leather bags which served as the common carriers for the milk, naturally, were not easy to clean, and sterilization was difficult, in fact, unknown. The prevailing temperatures were for the most part high enough to promote the growth of microörganisms. Fermentation obviously took place in the milk. Thus the fermented milk beverages which we know today were purely products of circumstances.

Most of these beverages originated among the tribes in southern and eastern Europe, especially in Russia, the Balkan States, and along the Mediterranean. Some were known in the Scandinavian provinces. Asia, Africa, and South America certainly contributed some characteristic fermented milks.

Many of these beverages are, of course, still prepared in Europe. Some of them have come into use in this country, where control of the fermentation by selection of cultures of yeasts and bacteria has been more exacting.

These fermented-milk beverages form a very interesting link between primitive and modern dairying. The fermentations which microörganisms could produce were known long before the organisms themselves were known. Further than this, these milk beverages have meant an increased consumption of milk through the ages and today we see, serving as adjuncts to the diet, beverages which have actual regulating and medicinal value in the control of intestinal fermentation.

Koumiss. These beverages have been known under many exotic names. There is one known as "Kumyss" ("Koumiss") which originated with a Russian tribe living along the river Kuma. Milk-souring types of bacteria and yeasts are predominant and bring about a rapid production of lactic acid and alcohol, with the evolution of gas which causes strong effervescence. In some sections of Asia, a brandy-like beverage is distilled from this type of fermented milk.

Kefir. Another product of southeastern Russia is known as Kefir (Kephir). Here also yeasts and lactic-acid bacteria produce quantities of acid, alcohol, and carbon dioxide. An interesting feature of this drink is the starter which is used. This consists of the so-called "Kefir grains," the origin of which is not known. They resemble small cauliflowers and carry the yeasts and bacteria necessary for the fermentation.

Leben. In Egypt, Syria, Algeria, Sardinia, Sicily, Montenegro, and Carpathia a beverage known variously as "Leben," "Leben raib," "Gioddu," etc., is likewise prepared by the action of yeasts and bacteria which produce acid and alcohol, principally.

Yoghurt. One of the most famous fermented-milk preparations is known as "Yoghurt" or "Matzoön." The renowned Metchnikoff called especial attention to this in his book on the prolongation of life among the Bulgarian tribes. He attributed this longevity to the use of this beverage, especially the presence of certain types of bacteria, one of which is now known as *Lactobacillus bulgaricus.* Some of his observations were inaccurate, but the publicity which was given to milk beverages as agents to promote health and insure long life still carries its impetus into our present-day dairy advertising. This Yoghurt is known under other names in many countries, such as Turkey, India, and the Balkan States. Several types of bacteria and yeasts have been described as being present. The principal characteristic is a high acidity produced largely by the *Lactobacillus bulgaricus* type. The present-day Bulgarian buttermilk has its origin in Yoghurt. It is prepared from pure cultures of the above-mentioned organism or with combinations of *Streptococcus thermophilus* starters.

Scandinavian Products. In Scandinavia, Kaeldermaelk, Taette, Püma, Fiili, Lange-milch, Lange-wei, etc., have been used for some time. Most of these are rather ropy as well as sour, and are produced largely by the action of the lactic-acid type of streptococcus.

Cultured Buttermilk. One of the favorite milk drinks in this country is the so-called "cultured buttermilk." This is prepared principally from sweet, fresh milk by the addition of ordinary butter starters which contain *Streptococcus lactis and Streptococcus citrovorus* or *Streptococcus paracitrovorus*. The acidity is not over 1 per cent, and the flavor is mild and pleasing.

Therapeutic Value of Fermented Milk. In recent years, attention has been called to the marked therapeutic value of milk cultures of an organism which is a regular inhabitant of the intestines of man and animals, namely, *Lactobacillus acidophilus.* When this organism grows in milk, it produces lactic acid, which curdles the milk. A characteristic but pleasant flavor is also produced. When such milk is consumed regularly, the *Lactobacillus acidophilus* gains predominance among the bacteria in the intestinal tract and in so doing lessens the putrefaction taking place there because of the presence of other types of bacteria. Thus acidophilus milk has a beneficial effect and is often prescribed by physicians for persons suffering from intestinal disturbances.

CHAPTER XIV

DAIRY ARITHMETIC

Certain problems involving mathematics are met in the handling and sale of dairy products. The solution of these problems presents difficulties for many dairymen.

On the farm, the producer wishes to calculate the average daily and yearly milk production of his cows and the fat percentages; he may be confronted with the choice of selling cream with a certain fat percentage at a stated price per gallon of milk, or at a certain price per hundredweight.

In the milk plant, milk is gathered from many sources. The management is concerned with the mathematics involved in standardizing the product so that it may be of uniform composition from day to day. The cheese-maker is interested in the same questions. The ice-cream maker has his problems in preparing and calculating the composition of the ice-cream mix. The butter manufacturer is confronted with the calculation of the overrun and often of the neutralization of cream.

The proportion of the various constituents of milk is commonly expressed in terms of percentage. The use of decimals is, therefore, essential in the handling of the calculations concerning milk and milk products. In the presentation of the material to follow, it is assumed that percentage and the use of decimals are well understood.

CALCULATIONS OF INTEREST TO THE PRODUCER

Problem 1. Determining the Pounds of Fat in Milk. To determine the pounds of fat in a given quantity of milk when the percentage of fat contained in the milk and the pounds of milk are known, multiply the pounds of milk by the percentage of fat.

For example, assume that a cow produces 25 pounds of milk testing 3.8 per cent fat at one milking.

First reduce per cent to a decimal by moving the decimal point two places to the left, for example 3.8 per cent = 0.038.

Then

$$25 \times 0.038 = 0.95 \text{ (pound of fat produced).}$$

Problem 2. The Average Fat Percentage. It may be desirable to calculate the average fat test under a variety of conditions. The milk yield and fat percentage for a particular cow may be available by either milkings, days, or months, and it is desired to calculate the fat percentage for all the periods represented. In other cases, the milk yield and fat percentage for each cow in the herd are known and the average for the entire herd is wanted. In milk- or cream-receiving plants the total milk or cream delivered from each farm is known, the test may be available, and the operator wishes to know the true average fat percentage of the mixed product. In calculating averages under any of these conditions, the error is very often made of taking a direct average, that is, in adding the fat percentages together and dividing by the number of samples included in the total. This method will give correct results only in case each lot of milk or cream represented is of the same weight. If the amounts vary, an average derived in this way may be far from accurate, as illustrated by the following:

Milk, pounds	Test, per cent	Fat, pounds
200	5.0	10
600	3.0	18
100	4.0	4
—		—
Total 900		32

A direct average of the three tests would be 4 per cent (5 + 3 + 4 = 12; 12 ÷ 3 = 4). The total fat in 900 pounds of milk if it contained 4 per cent fat, would be 36 pounds (900 × 0.04 = 36). If the fat in each lot is calculated separately, however, and the total added, it will be found that the actual amount is 32 pounds. Clearly, the first method is incorrect. The *true average test* would be 3.5 per cent ((32 ÷ 900) × 100 = 3.5).

Finding the True Average Test. The correct way to calculate the average test is to determine the amount of fat in each unit separately, take a total of these to give the total fat involved, then divide this fat total by the milk total, and multiply the result by 100. The figure obtained is the true average test. The procedure is illustrated by the table shown on page 354 which represents, by months, the production of a certain cow for a year. The problem is to find the true average fat percentage for the year.

Then:

$$\frac{509.3}{10,346} \times 100 = 4.92 \text{ per cent.}$$

So the true average fat percentage for the year is 4.92 per cent.

The direct average obtained by adding the fat percentages for each month and dividing by eleven would equal 5.22 per cent. In that case, 10,346 pounds of milk would contain 540 pounds (10,346 × 0.052 = 537.99) of fat, which is clearly incorrect, as the sum of the pounds of fat produced during the year is actually 509.3 pounds. An error of the type illustrated is often made in keeping yearly records of cows. Sometimes the milk seller calculates an erroneous average of this kind for his herd from the report of the cow tester and is led, thereby, to question the accuracy of the test he receives from the milk buyer.

Milk, pounds	Fat, per cent	Fat, pounds
1,319	4.30	56.7
1,351	4.30	58.1
1,241	4.40	54.6
1,156	4.20	48.5
1,119	4.40	49.2
956	5.40	51.6
872	5.40	47.1
789	5.50	43.4
709	6.10	43.2
472	7.60	35.9
362	5.80	21.0
Total 10,346		509.3

Problem 3. The Price of Milk. Milk is sold, as a rule, by weight and according to the fat content. A basic price is generally set per 100 pounds of milk of a given fat percentage. A certain sum per 100 pounds is generally added to the price for milk testing above the standard set and a proportionate amount deducted for milk testing below the standard. To illustrate, milk may be paid for in a given locality at the rate of $2 per 100 pounds of 3.5 per cent milk. For all milk testing above 3.5 per cent milk fat, 4 cents per point (each, 0.1 per cent), are added to the basic price, and for all milk testing below 3.5 per cent fat a like amount per point is deducted.

If a producer under the above conditions delivers milk testing 3.8 per cent fat to a milk plant, the value per 100 pounds becomes $2.12

$$(2.00 + (3 \times 0.04) = 2.12),$$

since the test is 3 points or 0.3 per cent higher than the standard set. If the test had been 3.2 per cent fat, or 3 points lower, the milk would have been paid for at the rate of $1.88 (2.00 − (3 × 0.04) = 1.88) per 100 pounds of milk. Other methods of paying for milk, based upon the combined market value of the milk fat and the milk solids-not-fat, are used in a few localities: particularly, in those where milk is bought for cheese making, drying, or condensed-milk manufacture.

To Determine the Value of Cream Sold by the Gallon. Frequently, the producer of cream sells this product by the gallon. The question arises under such circumstances as to the price received for milk fat. To illustrate such a problem, assume that cream containing 20 per cent of milk fat is being sold at 70 cents per gallon. The price per pound received for fat in this instance is calculated as follows:

Problem 4. To Determine the Pounds of Cream in One Gallon, Testing 20 Per Cent Butter Fat. One gallon of water weighs 8.34 pounds. The specific gravity of 20 per cent cream is 1.011 (see Appendix). The weight of 1 gallon of this cream is 8.4 pounds (8.34 × 1.011 = 8.43174). A gallon of cream weighing 8.4 pounds and containing 20 per cent milk fat, therefore, contains 1.68 pounds of milk fat (8.4 × 0.20 = 1.68). From this result it is shown that, when cream sells for 70 cents per gallon, the price received per pound of fat is 41⅔ cents (70 ÷ 1.68 = 41.66).

Problem 5. To Determine the Price per Gallon of Cream. It is often desired to sell cream by the gallon, and the question arises as to the charge that should be made per gallon for cream of varying fat content when the price desired for the fat so sold is known. Let it be assumed that it is desired to secure 40 cents per pound for milk fat. The cream to be sold is to contain 30 per cent of milk fat. The specific gravity of 30 per cent cream is 1.002. One gallon of water weighs 8.34 pounds; therefore, 1 gallon of 30 per cent cream weighs 8.35 pounds (8.34 × 1.002 = 8.35). Therefore 8.35 pounds of cream containing 30 per cent of milk fat will contain 2.51 pounds of milk fat (8.35 × 0.30 = 2.505). It is desired to secure 40 cents per pound of milk fat. Since 1 gallon of 30 per cent cream contains 2.51 pounds of milk fat, the value of this cream is $1.00 per gallon

$$(2.51 \times 0.40 = 1.004).$$

If it is desired to maintain the same price per pound of milk fat, sold as indicated in the above problem, for cream of varying tests, it is only necessay to form a problem in simple proportion. For example, if cream containing 30 per cent of milk fat must sell for $1.00 per gallon in order to net 40 cents per pound for milk fat, for how much per gallon should one sell cream containing 35 per cent milk fat?

$$0.30:0.35::\$1.00:x$$
$$0.30x = 0.35$$
$$x = \$1.166$$

Therefore, the price per gallon of 35 per cent cream should be $1.17.

Farm Separation Problems. In the separating of milk on the farm a number of questions arise which can be answered by the application of simple mathematics. It is commonly asked, how much cream of a given percentage of milk fat can be secured from a given amount of milk, and how much skim milk will result on the separation of milk when cream of a given percentage of milk fat is separated?

Problem 6. To Determine the Amount of Cream. To determine the amount of cream containing a given percentage of milk fat that can be expected from a given quantity of milk containing a definite percentage of milk fat, determine the pounds of milk fat in the milk and divide by the percentage of fat expected in the cream. To illustrate, assume that 800 pounds of milk containing 4 per cent of milk fat is to be separated and it is desired to know about how much cream containing 30 per cent of fat can be expected. The milk in this case will contain 32 pounds of milk fat ($800 \times 0.04 = 32$). If a cream containing 30 per cent of milk fat is desired approximately 106 pounds of this cream can be expected ($32 \div 0.30 = 106$). The loss of fat in the skim milk, in this case, is not considered of practical importance, assuming that milk consists of cream and skim milk. The approximate amount of skim milk that may be expected in the foregoing problem may be calculated by subtracting from the pounds of milk the pounds of cream expected. Thus it will be found that approximately 694 pounds of skim milk ($800 - 106 = 694$) may result. It may be stated that on the farm, 80 to 85 pounds of skim milk may be expected, as a rule, in the separation of each 100 pounds of milk.

Problem 7. To Determine the Most Profitable Market. Frequently, the producer of milk and cream is confronted with the problem of deciding the most profitable market where several possibilities are available. It may be a question of selling milk by the hundredweight, cream by the gallon, or cream to the creamery, where a definite price is paid for milk fat. Assume, for example, that the producer has the choice of selling milk at $1.80 per 100 pounds of 3.5 per cent fat milk, with 4 cents added for each additional point or 0.1 per cent; or to sell cream, to an ice-cream plant, to contain 30 per cent of milk fat at $1.20 per gallon; or to sell to a creamery manufacturing butter at 40 cents per pound of fat. Which of these will be the most profitable, or will yield the greatest returns? To solve the problem it is essential that the price received in each case be placed on a comparable basis. The most logical procedure is to compare the price received for milk fat under each plan. Since this figure is furnished for the fat sold at one creamery, it remains to determine the price offered under the two other plans.

It is essential that the average fat content of the milk produced be known, if an accurate analysis is to be made. Let it be assumed that the average fat content of the milk is 3.2 per cent.

It is further essential that cream be properly standardized, if sold to the ice-cream factory, or that an agreement be reached on the price per gallon paid for cream testing more than 30 per cent fat. This should be on the basis of the value of a 30 per cent cream at $1.20 per gallon.

The price receivable for milk fat, should the producer accept the plan of selling whole milk, should first be determined. A price of $1.80 is paid for 3.5 per cent milk with 4 cents a point added or subtracted for milk testing above or below the basic test. In this instance the value of 100 pounds of the milk produced would be lower than the basic price of $1.80, since the milk test is three points below the basic test (3.5 − 3.2 = 0.3). This would mean that the milk would be valued at 12 cents (3 × 0.04 = 0.12) below the basic price or $1.68 per 100 pounds (1.80 − 0.12 = 1.68). To determine the price received per pound of milk fat when $1.68 is received for 100 pounds of milk containing 3.2 per cent of milk fat, calculate the pounds of fat present in 100 pounds of such milk. The result is found to be 3.2 pounds (100 × 0.032 = 3.2). The price received for milk fat is found to be $0.525 (1.68 ÷ 3.2 = 0.525).

To determine the value of milk fat sold when $1.20 per gallon is received for cream testing 30 per cent of milk fat, it is first essential, as in the problem presented above, to know the weight of 1 gallon of 30 per cent cream. This was found in the calculation above to be 8.35 pounds. It was shown that 8.35 pounds of 30 per cent cream contained 2.51 pounds of milk fat. If the producer receives $1.20 per gallon for such cream, he will receive $0.478 per pound for milk fat (1.20 ÷ 2.51 = 0.478). It appears, therefore, in this instance, that the producer may select between receiving 52½ cents per pound fat at the milk plant, 48 cents at the ice-cream plant, or 40 cents at the creamery. It may be expected he would elect to sell at the highest price.

Selling Milk or Cream. When whole milk is sold from the farm, the problem of feeding calves, and perhaps other young stock, becomes acute. Such a case as presented in the preceding problem may involve the value the producer places on skim milk for feeding purposes. He may hesitate to sell the whole milk from the farm if the skim milk can be utilized to a good advantage as a feed for young stock on the farm. Let it be assumed, however, that the producer has use for but half of the skim milk which he produces and that he values this portion at being worth 30 cents per 100 pounds when fed to livestock. Assume the values in the above problem.

Since the price of milk is based on the unit of 100 pounds, calculate the skim milk available from 100 pounds of milk testing 3.2 per cent fat when the cream produced is to contain 30 per cent of milk fat when sold to the ice-cream plant in the above problem. It is essential to determine the amount of cream containing 30 per cent of milk fat that can be secured from 100 pounds of milk containing 3.2 pounds milk fat. This is found to be 10.7 pounds (3.2 ÷ 0.30 = 10.67). It is apparent, therefore, that there will be 89.3 pounds (100 − 10.7 = 89.3) of skim milk available. If one-half of this amount, or 44.7 pounds (89.3 × 0.5 = 44.65), is valued at 30 cents per 100 pounds, it is apparent that the value of this amount of skim milk is $0.134 44.7 × 0.003 = 0.1341).

If the farmer, therefore, values the skim milk in 100 pounds of milk at $0.134, it is necessary to deduct this amount from the price received for whole milk, if he chooses this plan of selling his product. In the above case, therefore, the actual price the farmer may assume would be received for milk containing 3.2 per cent of fat valued at $1.68 would be $1.55 (1.68 − 0.134 = 1.546). At the price of $1.55 for milk containing 3.2 pounds of fat, the value per pound of the fat would be $0.484 (1.55 ÷ 3.2 = 0.484). This price would still be greater than could be received for fat in cream for either the ice-cream plant or creamery.

The above calculation assumes, however, that the producer does not purchase feed for young stock deprived of milk when whole milk is sold on the farm. A possible procedure in such a case would be for the producer to purchase skim-milk powder to supplement the skim milk sold in the whole milk. It is calculated, above, that with each 100 pounds of milk sold the producer required 44.7 pounds of skim milk as feed for young stock. If whole milk is sold, this skim milk is not available, and the farmer is forced to purchase dry skim milk or a milk substitute.

If the producer purchases a like amount of dry matter in the form of dry skim milk as is contained in 44.7 pounds of skim milk the composition of these products must be known, or assumed, in making the calculation. For practical purposes, assume the skim milk to contain 9 per cent of total solids and the dry skim milk 95 per cent total solids. In 44.7 pounds of skim milk, therefore, there are 4.02 pounds (44.7 × 0.09 = 4.023) of total solids or dry matter. It will, therefore, require 4.2 pounds

$$(4.02 \div 0.95 = 4.23)$$

of dry skim milk containing 95 per cent total solids to supply the same amount of dry matter or total solids as is contained in 44.7 pounds of skim milk. At 7 cents a pound, 4.2 pounds of dry skim milk is valued at $0.294 (4.2 × 0.07 = 0.294). It appears, therefore, that it is necessary that the producer in the above instance deduct this amount from the sale price of the milk in order to secure the net returns when whole milk is sold. The net return would, therefore, be $1.39 (1.68 − 0.294 = 1.39) per 100 pounds of milk. If the net return on the basis of milk fat is then calculated, it is found that when 3.2 pounds of fat sell for $1.39, the value per pound of fat is $0.43 (1.39 ÷ 3.2 = 0.434). It appears, therefore, that the net return on selling whole milk, in this case, is larger than can be received when cream is sold to the creamery at $0.40 per pound.

STANDARDIZING MILK AND CREAM

One of the most typical calculations in the handling of milk and cream is that of adjusting the percentage of fat to a definite amount, commonly termed "standardization." Occasion for the standardization of milk and cream is more common in the market-milk plant, but it is also used in connection with the manufacture of such products as condensed milk, dry milk, cheese, and ice cream. In connection with all these products it is highly desirable that a uniform milk-fat content be present in the finished product.

To Decrease the Fat Content of Milk or Cream. Obviously, this may be accomplished either by taking out some of the fat or by diluting the original lot by mixing with it a quantity of the same class of material having a lower fat content. In the case of milk the common procedure would be to separate a portion and add skim milk to the remainder. If skim milk from another source were available, the proper amount of this would be used, making the operation of the separator unnecessary. The real problem is to determine how much fat should be taken out in the form of cream or how much skim milk should be added.

Problem 8. Reducing the Fat Content by the Use of the Separator. Let it be assumed that 500 pounds of milk containing 5 per cent fat are at hand and 400 pounds testing 4 per cent are desired. The fat contained in the 500-pound lot is 25 pounds (500 × 0.05 = 25) and in the desired 400-pound lot, 16 pounds (400 × 0.04 = 16). It is clear that 9 pounds of fat are to be removed by separation (25 − 16 = 9).

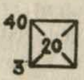
The problem is to determine how many pounds of milk containing 5 per cent milk fat will contain 9 pounds of milk fat. This is found to be 180 pounds (9 ÷ 0.05 = 180). It is, therefore, necessary to remove 180 pounds from the 500 pounds of milk containing 5 per cent milk fat. There will remain 320 pounds (500 − 180 = 320) of milk testing 5 per cent to which must be added 80 pounds of the skim milk that results on separation (320 + 80 = 400). The fat content of the milk so prepared is 16 pounds, or 4 per cent as desired (400 × 0.04 = 16), ((16 ÷ 400) × 100 = 4).

Problem 9. Addition of Skim Milk. It may not be necessary to separate a portion of the milk in the above calculation if skim milk from other sources is available. Assume, for example, that an unlimited amount of skim milk is available and it is desired to reduce the fat content of 500 pounds of milk from 5 to 4 per cent of milk fat. It is, again, necessary to calculate the pounds of fat contained in 500 pounds of milk containing 5 per cent milk fat which was found above to amount to 25 pounds (500 × 0.05 = 25). The problem, therefore, is to determine how many pounds of milk containing 4 per cent of milk fat can be made, using 25 pounds of milk fat. By dividing the pounds of fat available by the test of milk desired, it is found that 625 pounds (25 ÷ 0.04 = 625) of milk testing 4 per cent and containing 25 pounds of milk fat might be prepared from 500 pounds of milk containing 5 per cent of milk fat and skim milk. By subtracting the pounds of milk available (500) from the pounds of milk it is intended to make (625), which are to contain 4 per cent of milk fat, it is found that 125 pounds of skim milk should be added to prepare 625 pounds of milk testing 4 per cent.

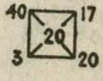
It is assumed that the fat content of skim milk is low enough to be of no practical significance. This is the common procedure in milk-plant work, but if extremely large quantities of milk are handled daily in condensed-milk factories, it may be advisable to take into consideration the fat content of skim milk. This would necessitate a chemical analysis of the skim milk in standardizing in order to insure accurate work.

Problem 10. Addition of Milk or Cream of Lower Fat Content. It is possible to reduce the fat content of milk or cream by the addition of milk or cream of a lower fat content. This involves a more complex problem, however, than has been previously reviewed as fat is present both in the milk it is intended to reduce and in the milk used for standardizing. The common practice is to use the so-called "square" method in connection with such problems, in order to simplify them. The following will serve to illustrate a problem of this type and the application of the "square" method of calculation. Assume it is desired to reduce the fat content of a cream testing 40 per cent of milk fat in the making of 500 pounds of 20 per cent cream and that milk containing 3 per cent of milk fat is available for standardizing.

Draw a square and connect the four corners with lines passing diagonally from one corner of the square to the other. In the center of the square, at the point where the two diagonal lines cross, place the figure representing the percentage of fat desired in the restandardized cream. At the left-hand corner, place the figures representing the percentage of fat in the cream to be standardized and in the milk to be used for standardizing. The square now appears as below:



Following along the diagonal lines, to the opposite corners at the right of the square, place the difference between the figures at the left-hand corner of the square and the center as follows:



The result of this calculation is to give the proportion of 40 per cent cream and 3 per cent milk (in this problem), which will result in a cream testing 20 per cent. The figure at the right-hand side of the square just opposite the figure on the left-hand side of the square refers to the same product: that is to say, in the above instance the figure at the upper right-hand corner refers to the proportion of cream testing 40 per cent required, and the figure in the lower right-hand corner refers to the milk testing 3 per cent required. The result of this calculation, as followed above, is that by mixing 17 parts of 40 per cent cream with 20 parts of 3 per cent milk, a total of 37 parts of 20 per cent cream will result (20 + 17 = 37).

It is desired to prepare 500 pounds of 20 per cent cream:

$$20:37::x:500$$
$$37x = 10{,}000$$
$$x = 270.2$$

Therefore, 270.2 pounds of 3 per cent milk will be required.
Then

$$17:37::x:500$$
$$37x = 8{,}500$$
$$x = 229.7$$

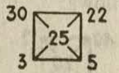
Therefore, 229.7 pounds of 40 per cent cream will be required.

From these calculations, it is found that 270.2 pounds of milk containing 3 per cent of milk fat should be mixed with 229.7 pounds of cream containing 40 per cent of milk fat, to prepare 499.9 (500 pounds desired) pounds of cream testing 20 per cent.

To check this problem, calculate the pounds of fat required in 500 pounds of cream testing 20 per cent which is found to be 100 pounds (500 × 0.20 = 100). Calculate the pounds of fat present in 270.2 pounds of milk testing 3 per cent, which is found to be 8.1 pounds (270.2 × 0.03 = 8.1). Also, the pounds of fat contained in 229.7 pounds of cream testing 40 per cent is found to be 91.88 pounds (229.7 × 0.40 = 91.88). The total of the fat supplied in the milk and cream is found to be 99.98 pounds

(91.88 + 8.10 = 99.98), (100 pounds desired.)

Problem 11. Standardizing a Given Quantity of Milk or Cream. In the above problem a definite quantity of a given cream was prepared from milk and cream of a given fat content. Frequently, it occurs that a given quantity of milk or cream is to be reduced in fat content, but the quantity of milk or cream which will result is unknown. Assume, for example, that it is desired to reduce 500 pounds of cream testing 30 per cent of milk fat to 25 per cent and that an unlimited quantity of 3 per cent milk is available for standardizing. By use of the square, the calculation is as follows:



The proportion is as follows:

$$22:5::500:x$$
$$22x = 2500$$
$$x = 113.63$$

Therefore, 113.63 pounds of milk testing 3 per cent are required.

By mixing 500 pounds of cream containing 30 per cent of fat, and 113.63 pounds of milk containing 3 per cent of fat, a total of 613.63 pounds of cream containing 25 per cent of fat will be obtained.

To prove or check the problem, the fat desired in 613.63 pounds of cream testing 25 per cent is found to be 153.4 pounds (613.63 × 0.25 = 153.4075). The fat contained in 500 pounds of cream testing 30 per cent of fat is found to be 150 pounds (500 × 0.30 = 150), and that in 113.63 pounds of 3 per cent milk, 3.4 pounds (113.63 × 0.03 = 3.4089). The total of the fat contained in the cream and in milk is found to be 153.4 pounds

(150 + 3.4 = 153.4),

the amount of fat required.

The reduction of the fat in milk or cream is frequently accomplished with skim milk. The square method can be used but, when the fat content is considered as zero, as is often the case in practical work, the square is not so essential in simplifying the calculation. If the skim milk is analyzed and its fat content considered in the calculation, the square simplifies the calculation, as in the above illustrations.

To Increase the Fat Content of Milk and Cream. The above calculations have dealt with problems which required the reduction of the fat content in milk or cream. It is frequently desired to raise the fat content of milk or cream, in which case it is necessary either to remove skim milk, to add cream, or to add milk or cream of a higher test; or to separate and remix the skim milk and cream. The procedures involve the same principles as those reviewed in reducing the fat content of milk or cream.

CALCULATIONS PERTAINING TO BUTTER

In the manufacture of butter, either on the farm or in the factory, certain calculations are essential to assist in the making of a uniform butter and in keeping the operator informed as to the results secured in churning. The common calculations include the determination of the overrun secured in churning cream, the estimated yield of butter from cream on churning, and the determination of the amount of salt or color to add.

Problem 12. Calculation of Overrun in Butter Making. When cream containing a definite amount of milk fat is churned, the amount of butter which results exceeds the milk fat. The reason for this is explained by the fact that butter contains in addition to milk fat, added salt, if salted butter is made, a small amount of curd, and water. The water content may amount to as much as 15.9 per cent of the total weight of the butter as previously referred to under the subject of butter making. The "overrun" is the term applied to the weight of butter which results in excess of the weight of milk fat churned. Overrun may be expressed in terms of pounds, or, as is usually the case, in terms of percentage. To calculate the percentage of overrun which results in churning cream, the pounds of butter in excess of the pounds of fat are first determined. By dividing the pounds of overrun by the pounds of fat churned, and by multiplying by 100, the percentage of overrun is secured.

For example, let it be assumed that 2,000 pounds of cream containing 30 per cent of fat or 600 pounds of fat yield 732 pounds of butter. To determine the pounds of overrun, the pounds of fat churned are subtracted from the pounds of butter which resulted. This subtraction reveals the fact that there are 132 pounds of overrun $(732 - 600 = 132)$. By dividing the pounds of overrun (132), by the pounds of fat churned (600), and multiplying by 100, it is found that the overrun amounts to 22 per cent $((132 \div 600) \times 100 = 22)$.

Problem 13. To Determine the Overrun from the Composition of Butter. It is frequently desired to estimate the amount of overrun secured in the manufacturing of butter when only the fat content of the butter is known from an analysis made. The calculation assumes no loss of fat in churning. Assume, for example, that a sample of butter contains exactly 80 per cent of fat—the minimum fat content that butter may contain, according to the federal laws. This means that in 100 pounds of this butter there are 80 pounds of fat. Therefore, if 80 pounds of fat resulted in the making of 100 pounds of butter, the difference between 80 and 100, or 20, equals the pounds of overrun. The percentage of overrun is 25 $((20 \div 80) \times 100 = 25)$. It should be clearly understood, therefore, that the maximum overrun that can be secured in the making of legal butter is 25 per cent.

Problem 14. Estimating the Yield of Butter. To estimate the yield of butter from the churn, it is essential, first, to estimate the overrun that is expected. The overrun expected is influenced by the composition of the butter and the loss of fat and butter in churning. Without going into a detailed discussion of these points, however, let it be assumed that an overrun of 22 per cent is expected on churning. If 200 pounds of fat are contained in the churn and 22 per cent overrun is expected, this will mean that 22 per cent of 200, or 44 pounds (200 × 0.22 = 44) of overrun will be secured. By adding the pounds of overrun (44) to the pounds of fat in the churn (200) it is found that 244 pounds of butter are expected from the churn (200 + 44 = 244).

Problem 15. To Calculate the Amount of Salt to Add to Butter. This is done in many different ways in the creamery and on the farm, as referred to under the subject of butter making. The amount of salt required, however, is first dependent upon the amount desired in the finished butter. If a butter containing 2.5 per cent of salt is desired, a slight excess of salt must be added to this amount, to maintain the percentage, as some of the salt is lost in the churn. The amount lost may amount to as much as 0.5 per cent in the large factory churns. This would mean that about 3 per cent of salt should be added, if the finished butter is to contain 2.5 per cent of salt. After determining the percentage of salt desired in the finished butter, calculate the amount of butter expected from the churn, as previously explained. If 400 pounds of butter are expected, it must contain 2.5 per cent of salt, or 10 pounds (400 × 0.025 = 10). In addition, 0.5 per cent is to be added in excess, which means that 3 per cent, or 12 pounds of salt (400 × 0.03 = 12) should be added.

After the above calculations and frequent analyses have been made, it is generally the practice in the creamery to reduce the salt calculation to a common figure, such as salt required per pound of butter expected, pounds of salt per pound of fat in churn, or the pounds of salt per can of cream in the churn. Reference was made to the common methods of determining the amount of salt required in making butter on the farm, under the subject of butter making.

Calculation of the Color Required. Color is added to butter at the rate of a given amount to each pound of finished butter expected or, as in the case of the addition of salt, according to the fat or amount of cream present, the more accurate method being the first mentioned. One ounce, or a certain number of milliliters, or a fraction of an ounce, of color is added per 100 pounds of finished butter expected. The calculation required in this case is simple.

Problem 16. Neutralization of Milk or Cream. The principle involved in the neutralization of milk or cream is based upon the chemical reaction which takes place when an alkali and an acid are brought together to form a salt. When an alkali such as lime hydrate ($Ca(OH)_2$) is used as a neutralizer in milk or cream, the chemical reaction which takes place between the alkali and the lactic acid of milk is as follows:

$$2C_3H_6O_3 \text{ (lactic acid)} + Ca(OH)_2 \text{ (lime)} = Ca(C_3H_5O_3)_2 \text{ (calcium lactate)} + 2H_2O.$$

The molecular weights of lactic acid and lime hydrate are 90 and 74, respectively. Since two molecules of lactic acid are required to neutralize one molecule of lime hydrate, it is apparent from the above equation that 180 grams (90 × 2 = 180) of lactic acid are neutralized by 74 grams of lime hydrate.

If it is desired, therefore, to calculate the amount of lime hydrate required to neutralize 1 pound of lactic acid, a problem in proportion may be set up and calculated as follows:

$$180:74::1:x$$
$$180x = 74$$
$$x = 0.4111$$

One pound of lactic acid is, therefore, completely neutralized by 0.4111 pound of lime hydrate.

The above calculation is correct when lactic acid is neutralized in water solutions and when the lime hydrate is chemically pure. For coarse work, such as is practiced in the creamery, it is assumed that the neutralizer used is 100 per cent chemically pure. It has been shown by Hunziker, however, that when lime is added to milk or cream, a portion of it attaches itself to the casein and about 20 per cent more lime than the theoretical calculation indicates is required to accomplish the desired results in practice.

Therefore, if in water solutions, 1 pound of lactic acid is neutralized by 0.4111 pound of lime hydrate, in milk or cream there would be required 20 per cent more lime, or an excess of 0.08222 pound

$$(0.4111 \times 0.20 = 0.08222);$$

or a total of 0.4933 pound of lime hydrate (0.4111 + 0.0822 = 0.4933).

Problem 17. When the above facts are available, the calculations in the creamery are simplified. Let it be assumed that it is desired to reduce the acidity of 2,000 pounds of cream with an acidity of 0.50 per cent to an acidity of 0.20 per cent. It appears, therefore, that the acidity is to be reduced by 0.30 per cent (0.50 − 0.20 = 0.30). If 0.30 per cent of lactic acid is to be reduced in 2,000 pounds of cream it is apparent that 6 pounds of lactic acid are to be neutralized (2,000 × 0.003 = 6). From the above calculations it was shown that 0.4933 pound of lime hydrate will neutralize 1 pound of lactic acid in milk or cream. If this is true, it is evident that 2.9598 pounds (6 × 0.4933 = 2.9598) of lime hydrate will be required to neutralize 6 pounds of lactic acid.

Neutralizers are not added to milk or cream in the dry form, but are diluted in water. A 20 per cent solution of the neutralizer is frequently used. In the above calculation, therefore, it would be essential to make a 20 per cent solution of the 2.9598 pounds of lime hydrate before it is added to the cream. This would mean that the lime hydrate should be made up to 14.799 pounds (2.9598 ÷ 0.20 = 14.799), with water, in the above calculation.

To calculate similar problems, as described above, using different neutralizers, it is only essential to follow the same procedure, taking into account their molecular weights in determining the amount of each required to neutralize 1 pound of lactic acid.

ICE CREAM

The calculations required in the manufacture of ice cream are more complex than are those discussed heretofore. Reference is made to the calculation of the ice-cream mix under the subject of ice-cream manufacture. It is possible, however, to calculate the composition of an ice-cream mix if the ingredients used are known. Frequently, in small ice-cream factories where a given formula is used, it is desirable to make such a calculation. No facilities may be available for chemical analysis, but the milk ingredients purchased are bought according to a guaranteed composition.

Problem 18. To Determine the Composition of an Ice-cream Mix. For convenience in calculating the composition of an ice-cream mix, construct a chart and list along the left-hand side the ingredients used in the mix, indicating their composition and the amount of each used. For example, let it be assumed that an ice-cream manufacturer is using a mix consisting of 211.42 pounds of 40 per cent cream; 231.2 pounds of plain condensed whole milk containing 11 per cent fat and 35 per cent total solids; skim milk which contains about 9.2 per cent total solids; sugar; and gelatin. Gelatin is calculated as containing 100 per cent total solids. The fat and total solids of each ingredient are calculated and classified as indicated below.

Ingredient	Pounds	Pounds, fat	Pounds, total solids	Pounds, sugar	Pounds, gelatin
Cream, 40 per cent fat, 45 per cent total solids.....	211.42	84.57	96.24		
Plain condensed whole milk, 11 per cent fat and 35 per cent total solids	231.20	25.43	80.92		
Skim milk, 9.2 per cent total solids............	412.38	......	37.88		
Sugar, 100 per cent.......	140.00	......	140.00	140.00	
Gelatin, 100 per cent......	5.00	......	5.00	......	5.00
Total................	1,000.00	110.00	360.04	140.00	5.00
Per cent...............	....	11	36	14	5

The total of the mixture is then secured and the total fat, total solids, sugar, and gelatin determined. By dividing each of these by the total pounds in the mix and multiplying by 100, the percentage of each is calculated.

In the above problem the total solids in the cream are given. If the analysis is not available, subtract the pounds of fat in the cream from the total pounds of cream and calculate pounds of solids-not-fat using the average composition of skim milk as the percentage of serum solids present.

Overrun in Ice Cream. The overrun in ice cream is based upon the increased volume of ice cream over that of the ice-cream mix. The ice cream, however, owing to its physical nature, readily takes up air in handling. This makes it difficult to secure an accurately measured sample. It is, therefore, more common to determine the overrun on the basis of the weight of a given volume of ice-cream mix as compared with the weight of a given volume of the finished ice cream. To illustrate, assume that 1 gallon of ice-cream mix weighs 9 pounds, and after freezing, 1 gallon of the finished ice cream weighs 5 pounds. If the difference in weight of 1 gallon of mix and 1 gallon of finished ice cream is divided by the weight of 1 gallon of finished ice cream, and multiplied by 100, it is found that the overrun secured in this case is 80 per cent ($9 - 5 = 4$, $(4 \div 5) \times 100 = 80$).

CHAPTER XV

MISCELLANEOUS TESTS

SAMPLING MILK AND CREAM

Milk and its products are subjected to chemical analysis probably more frequently than any food product. Of the analyses conducted on milk and cream, the milk-fat determination is the most common. The practice of paying for milk or cream upon the basis of the milk-fat content has become common in every section of America. In addition to the milk-fat analysis, however, milk and cream are frequently analyzed by commercial plants such as ice-cream factories, condensaries, and dry-milk plants for total milk solids. Not infrequently, when milk is bought and sold, it is subjected to tests which are designed to determine sanitary methods employed in the production and handling, the addition of preservatives or water, the ability of milk to withstand heat, etc. For each test to which milk is subjected, a small representative sample must be secured. Although the material, here presented, deals, primarily, with the sampling of milk for the milk-fat analysis, the reader should realize that the same precautions which are cited in the sampling of milk or cream for the milk-fat analysis are equally important in sampling milk for other purposes.

Importance of Sampling. In plants handling market milk or manufacturing the various milk products, a single milk-fat analysis may be the means of determining the milk-fat content of hundreds or thousands of pounds of milk or cream. A single test may involve hundreds of dollars' worth of the product. The importance, therefore, of securing an accurate and representative sample of milk or cream for analysis cannot be overemphasized. The greatest errors which occur in the testing of milk or cream do not occur in the operation of the Babcock test, but in the failure to secure a representative sample of the milk or cream to be analyzed.

How to Secure a Sample. Due to the difference in specific gravity between the milk serum and the fat of milk, the fat globules are continually rising toward the surface of milk or cream, and these products must be thoroughly mixed before a sample is taken for analysis. On the farm, the milk of an individual cow may be poured from one pail to another and a small sample of milk secured immediately. When larger volumes of milk are handled on the farm, the milk or cream should be thoroughly mixed by means of some device, such as a milk- and cream-stirrer, as is done in the receiving room of the manufacturing or milk plant.

It is exceedingly difficult to secure a representative sample of a given milk or cream when large volumes of it have been dumped into vats or pasteurizers. A small sample should then be taken at three or more different places in the vat. A sampling dipper may be used, or else a sampling tube, made for this purpose. For best results, milk and cream should be sampled when they are at a temperature between 60 and 90°F. (15.7 to 32.2°C.). If too cold, cream will be thick and viscous, and will be difficult to sample. Milk is more readily sampled at low temperatures than cream, as it does not become so viscous as the latter.

Sampling Frozen Milk or Cream. Reference was made previously to the manner in which milk or cream freezes. If frozen milk is sampled for analysis, and only the unfrozen portion secured in the sample, such a portion will contain the solids of milk, including the fat, in a more highly concentrated form than occurs in normal unfrozen milk.

This is also true of thin cream or cream containing less than 30 per cent of milk fat. By warming frozen milk or thin cream, the frozen portion will melt, after which a sample for analysis may be secured. Should such milk or cream be solidly frozen, extreme care must be exercised in thawing. Sudden warming of such cream will encourage "oiling off" of milk fat. Under these conditions it is very difficult to secure an accurate sample.

When cream containing 30 per cent or more of fat is frozen, a sample of the liquid portion offers a representative sample, providing the fat was uniformly dispersed before freezing. Thawing of such cream is not necessary to secure an accurate sample. When solidly frozen, such cream may be sampled by scraping the top surface to the solid cream and chipping the frozen cream. The frozen chips should be weighed into the test bottle before melting if an accurate test of the sample is to be secured.

A special problem in sampling arises in the case of plastic cream or high-testing frozen cream which has been produced by a continuous process. If the separation process is not uniform, variations in test will occur not only between portions of the same container but also between containers of the same lot. If such is the case, a composite sample should be prepared by taking proportionate, representative samples from each of several containers in a lot.

Sampling Churned Milk or Cream. It is exceedingly difficult to secure a representative sample from milk or cream if the fat has partially churned. As a matter of fact, many commercial plants refuse to pay for milk or cream on the basis of a fat test made from such milk or cream. A reasonably accurate sample may be secured, however, if the product is heated to a temperature of 100 to 110°F. (37.8 to 43.3°C.) or to a point sufficiently high to melt the churned fat granules, and then agitated vigorously and a sample removed immediately. This same procedure may be followed in attempting to sample milk or cream over which a "cream plug" or a layer of partially churned fat appears.

Sampling Sour Milk or Cream. Sour milk or cream, in which coagulated casein is present, frequently must be sampled. Milk may be stirred thoroughly, agitated, and a sample removed as in sampling sweet milk. If the milk has stood for a period of time, however, and the cream which has formed has had an opportunity to dry over a part of the surface a tough layer which is very difficult to break and to distribute evenly, forms at this point. By warming the milk slightly during agitation, the butter fat may be liquefied and a sample secured.

Sour cream offers much the same difficulty as sour milk, and it frequently happens that some butter fat is interlocked with the coagulated casein. Lumps of curd should be broken down as finely as possible, during the warming of such cream, and a sample secured after thorough agitation. In the creamery receiving sour cream, the practice often followed is to agitate the sample thoroughly, and to use the so-called "McKay sampling" tube for securing the sample.

Preserving the Sample. Samples of milk for certain analyses may be preserved, until the time for making the determination, by adding such preservatives as corrosive sublimate, formalin, and bichromate of potash. For general analytical work formalin is to be preferred, as bichromate of potash and corrosive sublimate add to the solids of milk and, thus, influence analyses involving the total solids. These preservatives, however, serve when milk or cream is to be preserved for milk-fat analysis. The preservatives will be referred to more fully, elsewhere.

COMPOSITE MILK SAMPLE

A composite milk sample is one which, when properly prepared, represents two or more lots of milk. When it is desired to make one analysis which will be representative of all milk sampled, the sample is prepared by mixing small samples of milk from different lots of milk, in one container. For extremely accurate results, the amount of milk constituting each sample going into the composite must be in proportion to the amount of milk involved. The purpose of such a sample is obviously to reduce the number of analyses. It may be used in preparing milk samples for all types of chemical analysis where it is desired to secure one figure to represent all lots examined. It is used extensively, by milk producers, in connection with the records of the production of individual cows. A common plan is to prepare a composite sample covering 3 days each month.

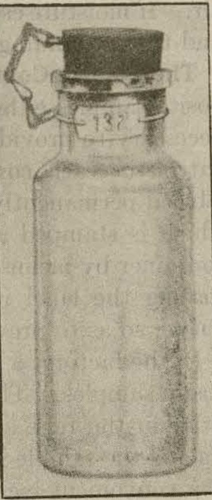


FIG. 86. The composite-sample bottle. A wide-mouthed bottle with a rubber stopper has been shown to be the most reliable and practical container for holding the composite milk or cream sample.

Even wider use of the composite test is made in connection with the purchase of milk at creameries, cheese factories, condensaries, and milk-receiving stations. To make certain of the quality of the milk received, the operator must make a daily milk-fat test of the milk delivered by each patron, or prepare a sample to which each delivery will contribute, and test this at intervals. As a rule, the period covered, when milk is purchased by the test, is either 1 or 2 weeks. The labor saved, by the composite sampling system used in this manner, is clearly considerable. A man with suitable equipment can test about 150 samples in a day. Where milk is received from 150 producers daily, practically the full time of one man would be required to perform the tests.

The equipment required for preparing composite samples, methods of taking the sample, preservatives used, and the application of the method of sampling cream are discussed in the following paragraphs.

Equipment Required. The equipment required for preparing a composite sample is an airtight jar, a sampling tube or dipper, and a suitable preservative. Any type of container may be used provided it is airtight. As milk contains a high percentage of water, evaporation of moisture will occur readily if exposed to the air. If moisture escapes, the milk will become more concentrated and the fat reading obtained, consequently, will be too high.

The Sample Container. In making preparations to take composite samples either at the creamery or at the dairy farm, it is necessary to provide at least one sample container for each milk patron or each cow in the herd. These containers should be labeled permanently. This can be done by using a metal tag on which is stamped a number and which can be attached to the container by means of a wire. A gummed label may be used by coating the label with white shellac, after it is pasted on the bottle, so as to prevent its soaking off during washing.

In the factory, a rack should be provided for holding the composite samples. The containers should be arranged in a definite order in the rack so that time may be saved by the worker in placing the sample in the container. This rack should be placed in a convenient location and care should be taken that it is not exposed to direct sunlight.

Taking the Sample. The sample of milk to be used as part of the composite is taken either with a sampling tube or with a small dipper. The object of using a sampling tube is to regulate the quantity of milk taken in proportion to the amount of milk sampled. The reason for this will be readily understood. If the same amount of milk were sampled each time, a dipper which holds a definite quantity would be satisfactory. For example, suppose three lots of milk of 100 pounds each were sampled:

Pounds, milk	Percentage, fat	Pounds, fat
100	3	3
100	5	5
100	6	6

The fat percentage in the composite sample would be 4.66, which is clearly correct. Suppose, however, in place of the three lots of milk each weighing 100 pounds there were considerable variations in the weights of the milk sampled:

Pounds, milk	Percentage, fat	Pounds, fat
500	3	15
200	5	10
50	6	3

In this case, a composite sample, made by taking the same quantity from each lot, would give the same result, a direct average of the fat percentage in the three lots, namely 4.66. If this figure is used, however, apparently 36.35 pounds of fat were delivered. As a matter of fact, the actual amount would be 28 pounds. Had, however, the sample been made up by using a sampling tube, the amount taken from each delivery would be in proportion to the amount delivered, and the average test would not have been 4.66, but the correct figure, 3.86.

The Dipper Method. As indicated, a small dipper with a capacity of 1 ounce is sometimes used. As this plan results in taking the same quantity regardless of the amount of milk sampled, it should be used when there is much variation in the amount of milk sample—or when wide variations occur in the fat percentages from one lot to another. The practical question often arises regarding the seriousness of the errors resulting from the use of this convenient method in sampling daily deliveries of milk delivered by milk patrons to the milk plant, creamery, cheese factory, or condensary. It should be recalled that, although there is some variation in the percentage of fat of individual cows, there is very little variation in the percentage of fat in the mixed milk from a herd from day to day. Practical experience as well as experimental evidence teaches that for all practical purposes the sampling dipper may be used with all the assurance of accuracy desired when it is used on mixed herd milk, when the milk is properly stirred before taking the sample, and when equivalent amounts are involved each day.

The Sampling Tube. There are on the market several different types of milk-sampling tubes, all of which, when properly used, will result in the securing of an accurate sample. There are two distinct advantages of the sampling tube over the dipper method of securing the sample for the composite: (1) The sampling tube results in the securing of the sample in aliquot portions, as the amount taken always represents the same fraction of the quantity of milk sampled. (The container holding the milk should have straight sides and be of equal diameter throughout.) (2) The sampling tube provides a fairly representative sample regardless of how long the milk may have stood before sampling, since by this method a column of milk which represents the milk from top to bottom is removed from the container.

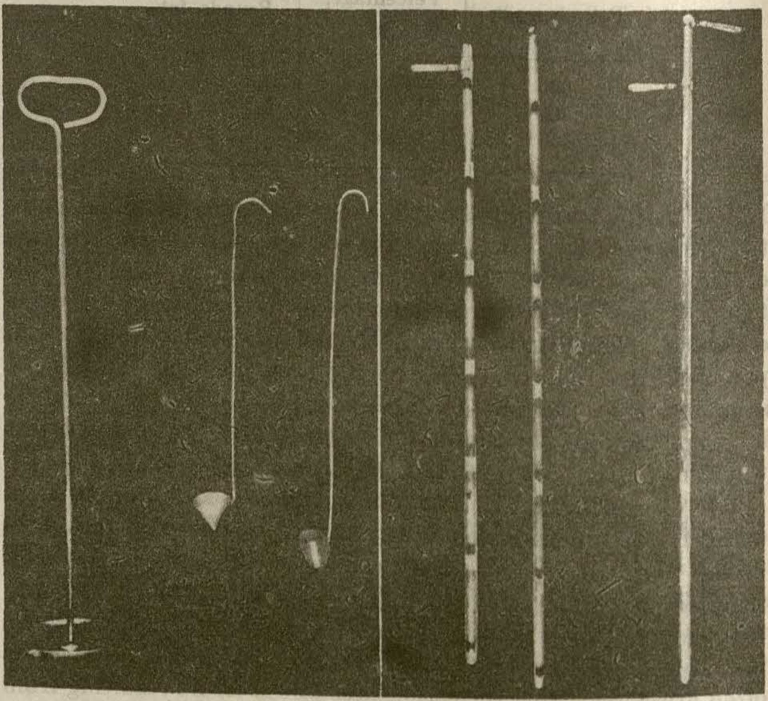


FIG. 87. Milk- and cream-sampling equipment. At the left is shown a common milk- or cream-stirring rod with which the sample may be stirred and a sample removed. The small dippers are commonly used for removing milk samples in plants receiving milk. The McKay sampler at the right is shown in separate parts, and as it appears when ready for use.

Preservatives for the Composite Sample. If the composite milk sample is to be successful, the milk must be kept sweet during the period while the sample is being assembled. This is accomplished by the use of a preservative. It is a good plan to place the preservative in the empty bottle before milk is added. Several preservatives are used:

Corrosive Sublimate. Mercuric chloride or corrosive sublimate is one of the strongest preservatives used for this purpose. A comparatively small amount will keep milk from souring and decomposing for such time as is necessary in using the composite-test system. As this chemical is highly poisonous, the common practice is to add a dye, usually bright red, in order to prevent some one from using the preserved milk by mistake for food. This preservative is prepared in tablets containing a definite amount, together with coloring material. The presence of the corrosive sublimate does not interfere with the Babcock method.

Formalin. Formalin (40 per cent solution of formaldehyde) is a very effective antiseptic and preservative. Since formalin comes in a liquid form, it is very convenient to handle. Approximately 1 milliliter or 28 drops will serve as a preservative for 1 quart of milk for a week or more. One objection often raised against the use of formalin is that it causes a hardening of the casein of milk, thus making it more difficult to test. This same objection may be offered against corrosive sublimate if it is used in excessive amounts. If, however, during the operation of the Babcock test, a little more time is given for the action of the acid on the casein, very little trouble will be experienced from the use of either of these preservatives. Formalin, like corrosive sublimate, is inexpensive.

Bichromate of Potash. Potassium bichromate or bichromate of potash comes in powder or tablet form. Although not so effective as corrosive sublimate or formalin, this preservative has certain advantages. It colors the milk a deep yellow without the addition of extra coloring material. Further, it is not so violent a poison and, therefore, not so dangerous to handle. It has several decided disadvantages, however, compared with formalin and corrosive sublimate, and is seldom used.

Composite Cream Sample. It is conceded that composite samples should not be made from thick sour cream. Cream which has soured and become extremely viscous is too difficult to sample and cannot be readily measured with the ordinary equipment available or in use. It has been shown, however, at the Minnesota Experiment Station that with sweet cream the composite-sample system is equally as accurate as daily testing. As a matter of fact, the work at that station hints that inaccuracy is more apt to occur where a daily cream sample is tested than when a composite is tested, because of the possible error in reading the cream test several times during a given period, compared with one reading, as is the practice when the composite sample is used.

Care of the Composite Sample. The most important precaution is to use containers that are completely airtight. Glass-stoppered bottles, often assumed to be the best, have been found unsuitable, as the stoppers do not fit tightly enough to prevent evaporation. Cork stoppers absorb fat from the sample and are, therefore, undesirable. The best stoppers to use are those of rubber. The samples should be kept in a cool place, away from direct sunlight. There is little danger of evaporation during the fall and spring months, but during the winter months, it is advisable to guard against keeping the samples in warm, dry rooms or close to the radiators, etc., used in heating the rooms. In some localities, the temperature of the room may become excessively high in the summer, making it advisable to place the samples in a cooler place. The sample should be agitated, on the addition of a new sample, to prevent the drying of milk on the sides of the container.

Testing the Composite Sample. Care should be taken in testing the composite sample to make sure that fat is thoroughly and evenly distributed throughout the sample. Care should also be taken to avoid the formation of masses of cream which must be melted. The sample bottle should be placed in a water bath at 90 to 100°F. (32.2 to 37.8°C.) for a few minutes, in order to make possible a thorough distribution of the fat on agitation.

MODIFIED BABCOCK TESTS

Testing Skim Milk, Buttermilk, and Whey. The regular Babcock test procedure has proven unsatisfactory for skim milk, buttermilk, and whey. Normally these products not only contain a very small amount of fat, but they contain a higher proportion of the smaller fat globules than whole milk or cream. It is known that some of the smaller globules are not recovered in the Babcock test, and one compensates for this in the method of reading milk and cream tests. In the case of skim milk, buttermilk, and whey, however, the amount of fat present is so small that the error involved, due to the large proportion of fat globules escaping recovery, is so great that the reading never approaches the true percentage of fat. In view of this difficulty, attempts have been made to modify the Babcock test for these products in order to obtain results which agree more closely with those obtained when using ether extraction methods.

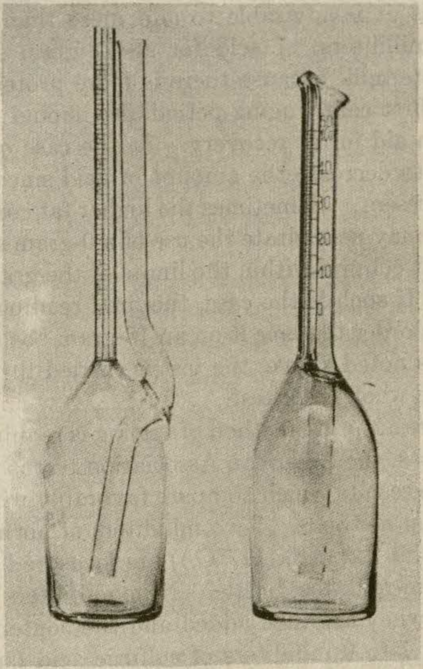


Fig. 88. **Bottle for testing skim milk and buttermilk. The same procedure is used as for whole milk. The scale allows readings to $\frac{1}{100}$ of 1 per cent.**

Because of the small amount of fat present in skim milk, buttermilk, and whey, special test bottles have been designed to increase the accuracy of reading. These are double-necked bottles such as those shown in Fig. 88. One neck, designed for the fat column, has a small bore with a capacity either of 0.25 or 0.50 per cent and graduated in 0.01 per cent divisions. The other neck, the filling tube, is larger and extends nearly to the bottom of the bottle. Both bottles are designed for an 18-gram sample. When centrifuging, these bottles must always be placed in the cups with the filling tubes toward the center of the wheel.

Although the regular Babcock test may show low results when testing skim milk, buttermilk, and whey, the results have been used quite widely to give an indication of the efficiency of separation, churning, and fat retention in cheese making. If used for such purposes, it is advisable to add more than 17.5 milliliters (usually 20 milliliters) of acid for an 18-gram sample of skim milk and buttermilk because there is more protein to be hydrolyzed. The first centrifuging period also should be increased to 10 minutes to aid in fat recovery. In the case of whey, it may be necessary to decrease the amount of acid since there is much less protein present. Sometimes the higher fat content of buttermilk or whey may necessitate the use of a 9-gram sample in order to keep the fat column within the limits of the graduated portion of the neck. If such is the case, the final reading must be multiplied by 2 in order to place it on an 18-gram basis. Other than the differences noted above, the test is carried through the same steps as in the whole-milk test.

When a more accurate method of testing is required in accounting for fat losses, the American Association test is recommended. This test gives results which compare favorably with those of the ether extraction methods. Two milliliters of normal-butyl alcohol (boiling point 242.6°F. (117°C.)) are measured into the filling tube of the skim-milk-test bottle. Nine milliliters of buttermilk, skim milk, or whey are then added and the contents thoroughly mixed. Next, 7 to 9 milliliters of sulfuric acid (specific gravity 1.82 to 1.83) are added. This is followed by thorough mixing. The bottles are then placed in the centrifuge (filling tubes toward center) and whirled 6 minutes. Hot water is then added to the base of the neck, the samples whirled 2 minutes, and additional hot water added to bring the fat into the neck. Following a third centrifuging period of 2 minutes, the samples are placed in a water bath at 135 to 140°F. (57.2 to 60°C.) for 5 minutes before reading. Since only a 9-gram sample was used, the actual reading must be multiplied by 2 to get the correct percentage.

Testing Cheese by the Babcock Method. Representative portions of cheese are chopped finely and thoroughly mixed. Exactly 9 grams of the sample are weighed into a 9-gram, 50 per cent, cream-test bottle. Twelve milliliters of hot water at about 170°F. (70°C.) are added and the mixture is thoroughly agitated. Next, 17.5 milliliters of sulfuric are added in small portions, with careful shaking after each addition, until the cheese curd entirely disappears and a dark-brown mixture is obtained. The test is then completed as when testing cream.

Testing Ice Cream. The regular Babcock test procedure cannot be used successfully in testing ice cream because of the carbonization of the sugar which interferes with the reading of the fat column. In an attempt to overcome this difficulty, many modifications of the Babcock method have been developed for testing ice cream for fat. Those tests which appear to be practical and reliable are described, namely, the Pennsylvania, Nebraska, Illinois, Minnesota, and perchloric acid-acetic acid methods.

When testing ice-cream mix the same precautions in sampling must be observed as when testing cream. Frozen ice cream must be placed in an airtight container and carefully melted in a warm-water bath before mixing and sampling for the test. Care must be exercised to prevent oiling-off or churning.

For testing ice cream, a special 9-gram, 20 per cent, ice-cream test bottle with 0.20 per cent graduations has been developed. Many prefer to use a 9-gram sample in a standard 8-per cent, 18-gram milk-test bottle; however, the actual reading must be multiplied by 2 in this case in order to obtain the correct percentage by weight. A cream-testing scale may be used for weighing the samples.

The Pennsylvania test developed by Swope requires the use of ammonium hydroxide (28 to 29 per cent ammonia), normal butyl alcohol (boiling point 242.6°F. (117°C.)), and diluted sulfuric acid (specific gravity of 1.72 to 1.74). The acid is prepared by adding carefully 3½ parts, by volume, of commercial sulfuric acid, specific gravity 1.82 to 1.83, to 1 part water, in a heat-resisting glass container.

The Pennsylvania test is conducted in the following manner after weighing 9 grams of the prepared ice-cream sample into the test bottle: (1) add 2 milliliters of ammonium hydroxide from a burette, (2) mix for approximately ½ minute, (3) add 3 milliliters of butyl alcohol from a burette, (4) mix for approximately 1 minute, (5) add 17.5 milliliters of the diluted sulfuric acid,

(6) mix thoroughly until digestion is complete, (7) place the bottles in the centrifuge and whirl 5, 2, and 1 minutes, adding hot water as in the regular Babcock milk test, (8) place the bottles in a water bath at 135 to 140°F. (57.2 to 60°C.) for 5 minutes, (9) allow a few drops of glymol to run down the inside of the neck of the bottle just before reading, and (10) measure the length of the fat column from the lowest point to the line separating the glymol and fat.

The Nebraska test for ice cream, devised by Crowe, employs two reagents, designated as A and B. Reagent A consists of 90 milliliters of normal butyl alcohol and 10 milliliters of chemically pure ammonium hydroxide. Reagent B consists of a mixture of equal parts of sulfuric acid (specific gravity 1.82 to 1.83), and ethyl alcohol (pure 95 per cent) or specially denatured according to Formula 30. This mixture is prepared by pouring the acid carefully down the side of a heat-resistant glass container to form a layer under the alcohol. The mixture is then stirred with a glass rod and cooled before using. Both reagents must be kept in tightly stoppered glass bottles. If denatured alcohol is used in preparing Reagent B, a light-brown color develops in several days at room temperature, indicating decomposition. When this occurs, it should be discarded and a fresh supply made.

The Nebraska test is conducted as follows: (1) weigh 9 grams of the prepared sample of ice cream into the test bottle, (2) add 5 milliliters of Reagent A and mix thoroughly by shaking, (3) add 30 milliliters of Reagent B and shake the contents until all the curd is dissolved, (4) heat the bottles in a water bath at 175 to 180°F. (79.4 to 82.2°C.) for 15 minutes and shake contents at least three times during this interval, (5) whirl bottles for 5 minutes in centrifuge, (6) shake contents thoroughly and then add water at not less than 180°F. (82.2°C.) to raise the level to within ¼ inch of the base of the neck, (7) whirl bottles for 3 minutes, (8) shake again if any curd appears and then add water at 180°F. (82.2°C.) to raise the fat within the graduated neck, (9) whirl bottles for 1 minute, (10) temper the bottle in a water bath and read as directed for the Pennsylvania test described above.

The Illinois modification for testing ice cream was introduced by Overman and Garrett. This method employs two alkaline reagents designated as A and B. Reagent A consists of 75 milliliters of normal butyl alcohol and 15 milliliters of ethyl alcohol (95 per cent). Reagent B consists of 200 grams of trisodium phosphate (commercial grade), 150 grams of sodium acetate (commercial grade), and 1 liter of water. The latter solution must be warmed to dissolve the salts before using if any crystallization has taken place upon standing.

The test is conducted as follows: (1) Weigh 9 grams of the prepared ice-cream mix into the test bottle. (2) Add exactly 2.5 milliliters of Reagent A and mix thoroughly. (3) Add 9 to 10 milliliters of Reagent B and again mix thoroughly. (4) Place the test bottles in a water bath and heat to boiling. (Shake the contents thoroughly two or three times while heating. Continue heating until the fat separates and forms a clear layer on the surface. This will take place in 15 to 20 minutes for plain ice cream and from 30 to 45 minutes for chocolate ice cream.) (5) Place the bottles in the centrifuge and complete the test in exactly the same manner as the regular Babcock milk test.

The Minnesota modification for testing ice cream employs an alkaline reagent. The original Minnesota Babcock Test Reagent consists of 110 grams of sodium carbonate and 200 grams of sodium salicylate dissolved in water and the volume made up to 1 liter. To this solution are added 30 milliliters of 50 per cent sodium hydroxide and 100 milliliters of normal butyl alcohol. Since the test was first introduced, a commercially prepared modified mixture of the reagents has been made available. The modified reagent may be prepared by dissolving 645 grams of sodium salicylate, 355 grams of potassium carbonate and 165 grams of sodium hydroxide in sufficient water to give a total volume of 3 liters. Next, add 1 liter of isopropyl alcohol. The reagent should be stored in a tightly stoppered glass container to prevent evaporation and absorption of carbon dioxide.

The Minnesota test is conducted as follows: (1) weigh 9 grams of the prepared ice-cream sample directly into a 20 per cent ice-cream-test bottle, (2) add 15 milliliters of the Minnesota test reagent and shake thoroughly, (3) digest for 12 to 15 minutes in a gently boiling water bath, having the bottles in a rack at least 2 inches above the bottom of the bath, (4) shake the mixture in the bottle vigorously when at least half the contents have turned dark brown (usually about 2½ minutes after placing them in the bath), (5) shake vigorously again about 1 minute later, being cautious at first in order to prevent the alcohol from boiling off through the neck, (6) centrifuge for ½ minute, (7) add water at 130 to 140°F. (54.4 to 60°C.) to raise fat into the graduated portion of the neck, (8) centrifuge for ½ minute, (9) place bottles in a water bath at 135 to 140°F. (57.2 to 60°C.) for 5 minutes, (10) add glymol, and measure the fat column from the lowest point to the line separating the glymol and fat.

The perchloric acid–acetic acid method for testing ice cream is one of the more recent modifications of the Babcock test for fat in ice cream. It was developed at the University of Illinois. The reagent used consists of equal parts by volume of 72 per cent perchloric acid ($HClO_4$–$2H_2O$) and 95 per cent glacial acetic acid.

Briefly, the procedure of the test is as follows: (1) weigh 9 grams of the ice-cream sample into a 20 per cent ice-cream-test bottle, (2) add 30 milliliters of the perchloric acid–acetic acid reagent and mix thoroughly, (3) digest the mixture by immersion in a boiling-water bath for 5 minutes, (4) add enough of the acid reagent to bring the fat into the calibrated stem of the bottle, (5) centrifuge the bottles for 2 minutes, (6) temper the bottles in a water bath, and read the fat column in the customary manner after the addition of glymol.

Testing Chocolate Milk. The Pennsylvania modification of the Babcock test is used for testing chocolate milk. Using the standard milk pipette, 17.5 milliliters of the properly mixed sample are transferred to the 8 per cent milk-test bottle. From this point, the test is conducted in the manner outlined above for the testing of ice cream by the Pennsylvania method.

Testing Sweetened Condensed Milk and Evaporated Milk. The regular Babcock test, as in the case of ice cream, is not suitable for testing sweetened condensed milk because of the charring action of the acid on the sugar present. Although evaporated milk contains no added sugar, poor results are usually obtained when the regular Babcock test is used. The Pennsylvania and Minnesota methods, as outlined above for the testing of ice cream, are recommended for the testing of these products.

To facilitate the weighing of sweetened condensed milk into the test bottle, it may be mixed with an equal weight of water.

For the Pennsylvania or Minnesota methods, weigh 9 grams of this mixture either into a 9-gram, 20 per cent, ice-cream-test bottle or an 8 per cent milk-test bottle. The results must be multiplied by 2 if the ice-cream-test bottle is used and by 4 if the milk-test bottle is used.

When testing evaporated milk by the Pennsylvania method, weigh a 6-gram sample either into an 8 per cent milk-test bottle or a 9-gram ice-cream-test bottle. Multiply the results by 3 when the milk-test bottle is used and by 1½ when the ice-cream-test bottle is used. For the Minnesota method, weigh a 9-gram sample into a 9-gram, 20 per cent, ice-cream-test bottle.

Testing Homogenized Milk. Lucas and Trout have suggested the following modified Babcock test procedure for testing homogenized milk: (1) temper the acid and milk to 70°F., (2) use sulfuric acid with a specific gravity of 1.83 to 1.835, (3) use the full amount of sulfuric acid (17.5 milliliters), (4) add the acid in three portions, 8, 5, and 4.5 milliliters, respectively, (5) mix the acid and milk by rotary motion after each addition and continue agitation for at least 15 seconds before adding the second and third portions of acid, (6) shake the tests in a mechanical shaker for at least 2 minutes before centrifuging, (7) complete the test according to the regular Babcock procedure for milk.

THE CALIBRATION OF BABCOCK TESTING GLASSWARE

Calibration of Glassware. In the early years, following the introduction of the Babcock test, inaccurately calibrated glassware was not uncommon. At present, only a small percentage of that put on the market is open to this objection. To help ensure the conditions necessary for accurate results, however, the laws of several states require that Babcock glassware sold within their boundaries be tested for accuracy of graduation. This often is done by the state experiment station at a small charge. Where this law is in force, companies selling glassware usually keep on hand a quantity of glassware which has been tested and stamped in accordance with the state law. Large individual users of testing apparatus also, at times, calibrate the glassware in use. Several methods are used but in all the first requirement is that the bottle shall be cleaned thoroughly, and shall be not merely apparently clean, but chemically clean.

With new glassware it usually is sufficient to wash with potassium bichromate cleaning solution and then to rinse several times with distilled water. Glassware that already has been used should be washed in a strong alkaline cleaning solution prepared by adding some common dairy cleaning powder to warm water. A brush should be used for this cleaning, particularly on the necks of the bottles. After rinsing, the glassware should be washed out with potassium dichromate cleaning solution and finally with distilled water.

Use of Plunger. One of the methods makes use of a small brass plunger. The thoroughly cleaned bottles are filled to the zero mark with a suitable liquid. (Many prefer a colored alcohol or water.) The plunger is made to give the correct volume at 70°F. (21.1°C.). For this reason, both the liquid and the plunger should be subjected to a temperature of 70°F. (21.1°C.) for some time before the work is begun. The procedure is to fill the bottle to a point slightly above the zero per cent mark with the liquid chosen, next carefully drying the inside of the neck by means of strips of blotting paper. By means of the blotter, sufficient liquid to bring the lower part of the meniscus (bottom of curved surface of liquid) exactly to the zero mark, is absorbed. The lower half of the brass plug is inserted in the liquid. The lower part of the meniscus should stand at the halfway mark on the scale; *viz.*, at the 4 per cent for the 8 per cent milk bottle, or at 25 per cent for the 50 per cent cream bottle. The upper half of the plunger should be lowered into the bottle. The reading is then taken at the highest mark on the scale. If higher or lower than this mark, the bottle is inaccurate and, if the variation is greater than the amount of one of the smallest divisions on the scale, the bottle is not considered accurate enough to use. The tolerances for Babcock test bottles are recognized as follows:

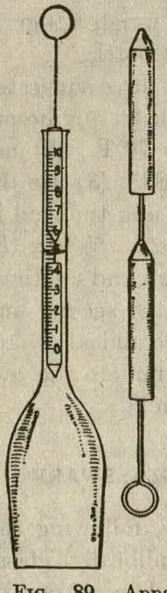


FIG. 89. Apparatus for calibrating milk-test bottles. By inserting the plunger into a Babcock test bottle previously filled to the zero mark, the accuracy of the graduations is determined.

8 per cent milk-test bottle, 0.1 per cent.
10 per cent milk-test bottle, 0.1 per cent.
50 per cent cream-test bottle, 0.5 per cent.
Skimmed-milk-test bottle, 0.01 per cent.
20 per cent ice-cream-test bottle, 0.2 per cent.

Calibrating with Water. A satisfactory method is to add water to the bottles from a small, accurately graduated burette. In this case, as in that of the brass-plunger method, the bottles are filled to the zero mark and the interior of the necks of the bottles dried with the blotter paper. The amount of liquid which should fill exactly the calibrated portion of the neck is added accurately by means of the burette. The level of the liquid then should coincide with the upper mark on the scale. This method is not satisfactory, as a means of calibrating the skim-milk bottle, because it is impossible to measure accurately the small amount of water needed; also, it is mechanically impossible to introduce the water directly into the small graduated neck.

Use of Mercury. Mercury may be used for measuring the volume of the graduation of test bottles and for this purpose generally is considered more satisfactory than water. The bottles to be tested must be perfectly clean and entirely dry. The amount of mercury needed is weighed out on an analytical balance. Mercury has a specific gravity of 13.5471 at 68°F. (20°C.) and this figure is used in determining the weight necessary to yield the correct volume for the graduations of the scale on the particular type of bottle to be tested. The correct amount of mercury is weighed out and poured into the bottle to be tested. A tightly fitting stopper is pressed in with one end at the upper point in the graduated scale. The bottle is then inverted and the accuracy of the graduated scale determined by noting if the mercury fills the volume from the lowest to the highest points. If care is used, the same mercury may be used for a great many determinations with only occasional reweighing to insure correctness. The mercury method is faster than the others when many bottles are to be tested. In addition, it has the advantage of being the most accurate.

The method of calibrating the skim-milk-test bottle differs from that described for other types in that no stopper is used. The carefully weighed mercury is allowed to flow into the small tube and is kept there by placing the finger at the top of the tube, much as one handles a pipette.

ROESE-GOTTLIEB FAT ANALYSIS

In milk condensaries, dry-milk, and ice-cream plants where large volumes of milk are handled, it is frequently necessary to determine the milk-fat content with extreme care. The equipment used frequently in these plants is known as the "Mojonnier tester," which is used in connection with a modification and a simplification of the Roese-Gottlieb method.

This method consists (see Appendix) of extracting the fat from the dairy product with ether. To the sample is first added, however, strong ammonium hydroxide which, dissolves the casein, neutralizes the acid present, and reduces the viscosity. Following the ammonia, a quantity of 95 per cent alcohol is added to the sample to prevent the formation of a gelatinous mixture, which occurs when ether is shaken with milk. To the sample is then added ether in which milk fat is soluble. Other milk solids-not-fat present in the ether solution are eliminated by the addition of petroleum ether to the sample. The solution of ether and fat is then poured off into an evaporating dish, the ether driven off by heat, and the ether extract weighed and reported as milk fat.

THE DETERMINATION OF SPECIFIC GRAVITY

Specific gravity is the ratio of the weight of a given volume of a substance to the weight of an equal volume of water at the same temperature. One milliliter of water at 39.2°F. (4°C.) weighs 1 gram; therefore, when a liquid is at a temperature of 39.2°F. (4°C.), its specific gravity is numerically equivalent to the weight in grams of 1 milliliter. It has been determined that the specific gravity of milk averages 1.032, so it is clear that 1 milliliter of milk weighs 1.032 grams.

Since the weight of a given volume of water at a given temperature is known, it is possible to calculate, from the weight, the volume of milk or cream, or from the volume, the weight upon the basis of the specific gravity of the substance, as illustrated in the following example:

One gallon of water at 39.2°F. (4°C.) weighs 8.344 pounds and since the average specific gravity of milk is 1.032, 1 gallon of average milk will weigh 8.344 × 1.032, or 8.61 pounds. The approximate specific gravity and weight per gallon of several milk products are given in the table on page 416 of the Appendix.

Value of Specific-gravity Determinations. It is distinctly advantageous in many instances to determine the specific gravity of milk. The percentage of total solids and solids-not-fat in a given milk can be estimated with reasonable accuracy if the specific gravity and fat percentage are known. This fact is widely used in the condensed- and dried-milk industries, where the yield of products is estimated from the total solids content of the milk. In condensing milk, the progress of concentration is observed by making specific-gravity readings of the milk.

The specific gravity may be used also as an indication of adulteration of milk with water, but not as definite proof of such irregularity. Some years ago, low specific gravity of milk was accepted as definite proof that water had been added. Now, however, it is recognized that milk is not necessarily adulterated, even though its specific gravity is low. When milk with low specific gravity is encountered, it should be considered suspicious and should be tested for watering by a more accurate method.

Specific gravity is most accurately measured by comparing, under carefully controlled temperature conditions, the weight of a volume of milk with that of an equal volume of pure water. In a practical way, this could be done by weighing water in a can filled level full and then refilling with milk at the same temperature as the water and reweighing. If the water weighed 62 pounds, and the milk 64 pounds, the specific gravity would be 64 ÷ by 62 = 1.032.

The Westphal Balance. For reasonably accurate work an instrument known as the "Westphal Balance" may be used. This instrument consists of a pivoted beam with a plummet or float attached to one end and calibrated to give direct readings of specific gravity. The balance is first set to give a reading of unity when the plummet is submerged in pure water at 60°F. (15.56°C.). When the plummet is submerged in a liquid heavier than water, such as milk, additional weight is required to rebalance the beam. The specific gravity is indicated directly by the position of the movable weights. The temperature of the samples must be controlled accurately for work with this instrument.

The Lactometer. As a matter of convenience, the specific gravity of milk usually is determined with a lactometer. The lactometer is a hydrometer with a scale adapted to the limits of the specific gravity of milk. Any hydrometer works on the principle that a body floating in a liquid sinks to such a level that it displaces a volume of liquid equal in weight to the floating body. In liquids of low specific gravity, the hydrometer sinks farther before displacing a great enough volume of the liquid to equal its own weight than in a liquid of higher specific gravity. Thus a scale may be placed on the stem of the hydrometer so as to read the specific gravity directly at the point level with the liquid floating the hydrometer. The lactometer is weighted to float in milk, and its scale is especially adapted to the range of specific gravities of milk.

Types of Lactometers. Several types of scales are used on lactometers. Three types are in general use, namely, the Quevenne, the New York Board of Health, and the Baumé lactometers. The Baumé lactometer is used for determining the specific gravity of concentrated milk products, whereas the other two types are designed for determinations on fluid milk. The Quevenne lactometer has been the most widely used for fluid milk because its reading is most readily converted into specific gravity. For this reason, the procedure for using the Quevenne lactometer is described here. There are two types of Quevenne lactometers on the market. One is calibrated in Quevenne degrees from 15 to 40 in 1-degree divisions and is recommended for use when only approximate results are required. The other type is calibrated in Quevenne degrees from 20 to 37 in 0.1-degree subdivisions. This latter type is considerably more accurate than the former and is recommended for routine use in the dairy plant.

Making the Determination. A representative sample, consisting of at least 1 pint of milk, should be obtained. It is desirable to hold the sample at a temperature of 50°F. (10°C.) or lower for at least 2 hours before making the determination, especially if the milk is freshly drawn or has been subject to agitation in transit so that considerable air has been incorporated. To determine the specific gravity, bring the sample of milk to a temperature of very nearly 60°F. (15.56°C.). Mix the sample by pouring it several times from one container to another, being careful to pour it against the walls of the containers to avoid incorporating air. Place the milk in a tall cylinder and immediately lower the clean lactometer gently into the milk. When the lactometer reaches a stationary position, take the reading at the top of the meniscus on the stem. Immediately after reading the lactometer the temperature of the milk should be determined and recorded.

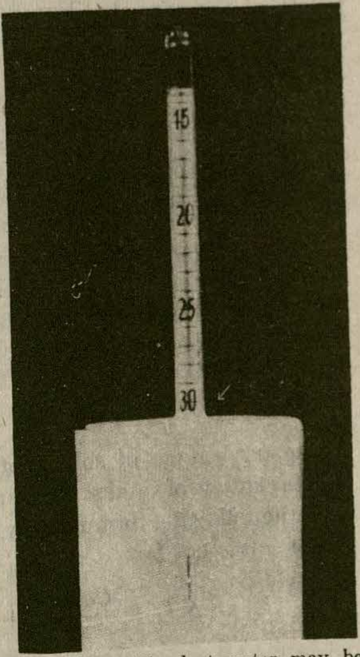


FIG. 90. The lactometer may be used in connection with the Babcock test for estimating the total solids of milk. The arrow in the above photograph indicates the point at which the lactometer is read by the operator.

Correction for Temperature. To determine the specific gravity it is first necessary to correct the lactometer reading for a temperature of 60°F. (15.56°C.), since lactometers are customarily standardized to be read at this temperature. For each degree Fahrenheit above 60°F. (or 1.8 degrees Centigrade above 15.56°C.), 0.1 must be added to the lactometer reading, while for each degree below 60°F. (1.8 degrees below 15.56°C.), 0.1 must be subtracted. The temperature correction is accurate only when applied within a few degrees of the standard temperature. The reading, corrected for temperature, is usually designated as "corrected lactometer reading" (*Corr. L*) and is used for calculating either specific gravity or total solids.

Calculation of Specific Gravity. The specific gravity of a milk is calculated from its corrected lactometer reading by dividing by 1,000 and adding 1. Thus, if the corrected reading were 32.5, calculate as follows:

$$Corr.\ L = 32.5$$

$$\text{Specific gravity} = \frac{32.5}{1{,}000} + 1 = 1.0325.$$

It is seen that the corrected lactometer reading really constitutes the last figures of the specific gravity and that no calculation is necessary if 1.0 is placed before the corrected reading.

Calculation of Total Solids. The total-solids content of milk may be estimated also from the corrected lactometer reading. In skim milk, the percentage of total solids is approximately one-fourth of the corrected lactometer reading. However, in whole milk the fat causes a decrease in the lactometer reading but an increase in the total solids. Furthermore, the percentage of solids-not-fat increases about 0.2 for each 1 per cent fat. Therefore, the following formula (commonly known as the "Babcock formula") has been found to yield approximately correct results for estimating the percentage of total solids:

$$T.S. = \frac{Corr.\ L}{4} + (1.2 \times \text{per cent fat}).$$

Example. Assume a corrected reading of 32 and a percentage fat content of 4.

Then,

$$T.S. = {}^{32}\!/_{4} + (1.2 \times 4) = 12.8 \text{ per cent.}$$

The percentage of solids-not-fat quite obviously is equal to the percentage of total solids minus the percentage of fat. Therefore, the following formula may be used to calculate the percentage of solids-not-fat:

$$S.N.F. = \frac{Corr.\ L}{4} + (0.2 \times \text{per cent fat}).$$

Using previous example,

$$S.N.F. = {}^{32}\!/_{4} + (0.2 \times 4) = 8.8.$$

Several other formulae have been proposed for the estimation of the total solids of milk in an attempt to obtain results which agree more closely with gravimetric methods. Formulae have also been devised for calculating the total solids of other fluid milk products from lactometer readings.

THE DETERMINATION OF ACIDITY IN MILK AND ITS PRODUCTS

The production of acid in milk is commonly termed "souring," and the sour taste of such milk is due to the presence of lactic acid. As has been pointed out elsewhere in this text, the souring of milk is caused by the action of bacteria which break down lactose to form lactic acid. The percentage of acid present in dairy products at any time is, therefore, a rough indication of the age and manner in which the milk has been handled previously.

There are two ways in which the reaction of milk or milk products may be expressed, namely, (1) the titratable acidity (or alkalinity), or (2) the hydrogen-ion concentration (or pH). The titratable acidity has been more commonly used in the dairy industry for many years but there are increasing instances of the adoption of the pH scale for specific purposes.

When the acidity of milk is determined by titration against an alkali, however, a part of the substances that neutralize the alkali are compounds other than lactic acid. If a regular acidity test is made of perfectly fresh milk, in which no lactic acid has been formed, an appreciable amount of acid-reacting substances will be detected. This reaction is due, partly, to certain acid salts of milk and, partly, to the alkali-binding capacity of the milk proteins. The amount of these substances in milk is equivalent in acid properties to from 0.10 to 0.18 per cent lactic acid. The titratable acidity of fresh milk usually is called natural acidity, and a milk showing less than 0.18 per cent titratable acidity, calculated as lactic acid, is looked upon as fresh and unfermented.

Use of the Acidity Test. The acidity test is of great value in grading milk and cream. Many of the microörganisms common to milk produce lactic acid from lactose, if held at favorable temperatures, and the determination of the lactic-acid percentage in cream is, therefore, a quick and practical means of differentiating between the products that have been well cared for, and those in which microbial action has been permitted. Many cream and milk buyers use the acidity test as one of the indices of quality in the products they purchase. It must be understood, however, that the acidity test is not the only index of quality in milk and cream. Disgusting odors and flavors are not detected by the acidity test, but are readily noted by the senses of taste and smell.

Use of Acidity Test in Dairy Manufactures. The acidity test finds many uses in controlling the manufacture of dairy products. One of its common applications is in the making of Cheddar cheese, in which the proper time to begin each successive step in the process of manufacture is indicated principally by the percentage of lactic acid developed. The butter industry finds a good use for this test in the handling of sour cream in preparation for churning. Before such cream can be pasteurized successfully the lactic acid must be neutralized and, in order to determine the correct amount of neutralizer to use in a given batch of sour cream, it is necessary to know the percentage of acid present. With the aid of the acidity test it is possible to neutralize sour cream to any desired point very accurately. Still further use of the acidity test is found in the technical control of ice cream and condensed milk. Also, some organizations make a specialty of selling fermented-milk drinks. The success in manufacturing these beverages is dependent on controlling the fermentation, and, in many cases, the acidity serves as an indication of the degree of development so that the procedure in making the drinks also can be controlled accurately.

Basis of the Acidity Test. The determination of the acidity of milk by titration with a tenth-normal solution of an alkali, such as sodium hydroxide, is based upon the fact that a given volume of a tenth-normal solution of an alkali will exactly neutralize an equal volume of a tenth-normal solution of an acid. In other words, each milliliter of a tenth-normal solution of sodium hydroxide (which contains 4.001 grams in 1 liter of solution) will neutralize 1 milliliter of a tenth-normal solution of lactic acid (which contains 9.006 grams in 1 liter of solution). As it is desired to calculate the percentage of lactic acid in a given amount of milk, and since 1 milliliter of a tenth-normal lactic acid contains 0.009 gram of lactic acid, the number of milliliters of a tenth-normal alkali necessary to neutralize the lactic acid in the sample, multiplied by 0.009, will give the number of grams of lactic acid in the sample. When this result is divided by the total number of grams of milk in the sample and multiplied by 100, the percentage of lactic acid in the sample will be obtained. This calculation may be illustrated more clearly by the following formula:

$$\text{\% of lactic acid} = \frac{\text{milliliters } N/10 \text{ alkali} \times 0.009}{\text{grams of sample}} \times 100.$$

As can be seen readily, this formula permits the calculation of the percentage of lactic acid in samples of various sizes. When the test was first developed, samples as large as 25 and 50 grams were used. In more recent practice, however, the amount has been reduced to 9 or 18 grams.

The Details of the Acidity Test. The materials needed for conducting acidity tests are a white enameled or porcelain cup, stirring rod, 9- and 17.6-milliliter pipettes, burette, 1 per cent alcoholic solution of phenolphthalein, and *N*/10 sodium hydroxide (4.001 grams made up to 1,000 milliliters with distilled water).

To make the test, the burette is filled with *N*/10 NaOH, care being taken that no air bubbles are entrapped in the lower part. The cup used should be clean. If milk, skim milk, or buttermilk is to be tested, by means of the 17.6-milliliter pipette, place 18 grams in the cup. If cream is to be tested, the 9-milliliter pipette may be used, for cream weighs about 1 gram per milliliter. When this volumetric procedure is followed, however, it is advisable to rinse the cream adhering to the walls of the pipette with 1 pipetteful of water. (The test is influenced slightly by the amount of rinse water used; therefore the sample should not be diluted too much.) More accurate results may be obtained by weighing the cream sample, in which case a 9- or 18-gram sample is a convenient quantity of cream. If ice cream or condensed milk is to be tested, it is well to weigh either 9 or 18 grams into the cup. After the sample has been measured or weighed into the cup, 0.5 milliliter (approximately 10 drops) of the phenolphthalein solution is added to serve as an indicator

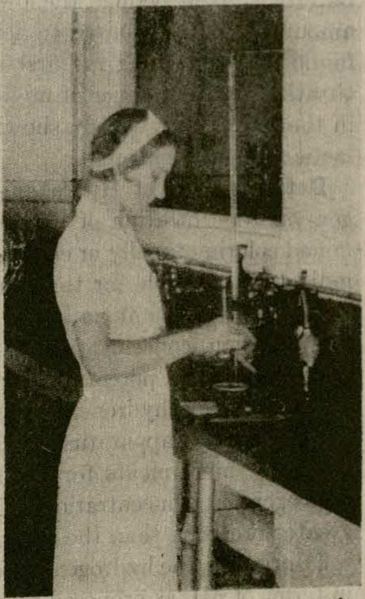


FIG. 91. The acid test. The equipment required in making the acid test of milk consists of a burette, a cup with a white lining, and a stirring rod. Titration is made using N/10 sodium hydroxide and phenolphthalein as an indicator. (*Courtesy of Land O'Lakes Creameries, Inc.*)

of the end point. The alkali is added next. The reading of the alkali in the burette at the lowest point of the meniscus is noted and the alkali allowed to flow slowly into the cup containing the sample; at the same time, the contents of the cup are stirred constantly. When a faint but definite and persistent pink color appears, the end point has been reached. The reading of the burette is taken again at the lowest point of the meniscus and the amount of alkali required to neutralize the acid in the sample is found by subtracting the first reading from the one made after titrating. The number of milliliters of alkali thus found is used in the formula previously shown to determine the percentage of lactic acid in the sample.

Determination of Hydrogen-ion Concentration. The hydrogen-ion concentration of milk or dairy products may be determined colorimetrically or electrometrically. There are numerous indicators available for the colorimetric method and the choice of any one or a combination of them depends upon the range of hydrogen-ion concentration to be measured. In the electrometric method, a potentiometer is necessary in combination with a hydrogen, quinhydrone, or glass electrode assembly. There are several kinds of apparatus available on the market providing the necessary instruments for the satisfactory measurement of the hydrogen-ion concentration. The electrometric method gives greater precision than the colorimetric method.

In practice, the hydrogen-ion concentration usually is expressed in terms of pH, as proposed by Sorensen. The pH, or hydrogen-ion potential, actually is the logarithm of the reciprocal of the hydrogen-ion concentration. On this scale neutrality is represented by pH 7.0. If the figure is below 7.0 it signifies acidity and if above 7.0, alkalinity. Actually a solution of pH 6.0, for example, has ten times the hydrogen-ion concentration of a solution at pH 7.0 and is therefore more acid in reaction.

It is not possible to convert titratable acidity directly into pH. There is some general relationship between the two measurements but each must be used and interpreted independently.

TESTS FOR SEDIMENT

Visible foreign matter in milk is objectionable for several reasons. The presence of dirt is an objection in itself, but it is, furthermore, an indication of carelessness in handling which usually means a lack of sanitation. Another chapter takes up this matter in greater detail and points out that conditions which cause visible dirt to find its way into milk are such that many microörganisms which decompose milk are usually added with the dirt. Furthermore, the presence of particles of visible dirt usually means that a considerable amount of other foreign matter has entered the milk but cannot be seen because it is in solution.

The retailer as well as the milk consumer is interested in clean milk. For this reason, the conditions on each farm where milk is produced are often rated by the use of a score card. The condition of the milk as delivered by the producer is also closely scrutinized. A differential in price may be made, depending upon the results of such examinations. One of the very objectionable conditions is the presence of visible dirt. The value of a method for determining the relative amount of insoluble sediment in milk is obvious. A crude method consists in looking for dirt at the bottom of milk bottles that have stood undisturbed for some time. A more reliable method consists of filtering a definite quantity of milk through a white cotton disc.

Determination of Sediment in Fluid Milk. Standard procedures for sediment testing have been published by the American Public Health Association and the Association of Official Agricultrual Chemists. In general, the method consists of filtering a pint of milk through a special lintine disc. The disc must measure 1¼ inches in diameter and must be held over a flat wire screen in the tester so as to expose a filtration area measuring 1⅛ inches in diameter. There are two methods of collecting samples. One, known as the "mixed-sample method," consists of thoroughly mixing the milk before removing the test portion. The other, known as the "off-bottom-sample method," consists of taking the sample off the bottom of the unstirred can of milk. The withdrawal of the pint sample must be synchronized with the movement of the head of the tester as it is moved once completely across the bottom of the can. The mixed-sample method is commonly used to determine sediment in milk during and after processing and in the final consumer package. The off-bottom method is used to measure the sediment in cans of raw, bulk milk when delivered by the producer.

The amount of visible dirt on the disc is usually estimated by comparing it with a set of standard discs to which have been added weighed amounts of sediment representing all degrees of cleanliness from "clean" to "very dirty." Definite scores may be established for each standard and the results of the test recorded accordingly. Some laboratories responsible for milk quality keep a file of sediment discs from the milk of each producer. This amounts to keeping a record of the care with which each producer handles his milk. Other milk plants paste the disc on a card and send it to the producer of the milk upon which the sediment test was made.

Determination of Sediment in Dairy Products. Standard tests have also been devised to detect the presence of extraneous matter or sediment in cream, butter, cheese, condensed-milk products, and dried milk. Special treatment of the sample prior to filtering is required in each case because of the physical nature of the products. Usually the product must be dispersed in hot water with the aid of acids, alkalies, or other chemical compounds to facilitate filtering. Special filtering apparatus is necessary in most cases.

ANALYSIS OF BUTTER AT CREAMERY

For all practical purposes butter consists of milk fat, moisture, salt, and curd. Butter also contains a small amount of milk ash and milk sugar, but in a creamery analysis these ingredients are not determined separately but are included with the protein under the designation of "curd." The butter maker is concerned primarily at present with the moisture and fat analyses, yet it is recognized that a complete analysis is essential when attempting to manufacture butter of a uniform composition.

There are two generally accepted methods of making a complete analysis of butter: (1) the procedure of the Association of Official Agricultural Chemists and (2) the Modified Kohman test. The first method, commonly called the "Official Method," is used principally by federal and state laboratories. The Modified Kohman test is preferred by the creameryman because of its greater simplicity, and, when carefully conducted, the results are sufficiently accurate for adequate control of butter composition. For this reason, an abbreviated description of the Modified Kohman test is presented.

Modified Kohman Test. *Equipment and Supplies.* In conducting the test the following equipment and supplies are essential:

Equipment:

1. A metal spatula.
2. A sample jar with tight-fitting, non-absorbent closure.
3. A metal beaker approximately 2 inches in diameter and 3 inches high.
4. A pair of crucible tongs.
5. A butter balance with sensibility reciprocal of not over 15 milligrams.
6. A 10-gram weight.
7. A source of heat such as a laboratory alcohol lamp or gas burner with tripod and asbestos mat, or an electric hot plate.
8. A cooling surface or desiccator for cooling beaker and contents to room temperature after heating and before weighing.
9. A metal disc or watch glass for covering beaker.
10. A glass stirring rod, preferably rubber-tipped.
11. A 50-milliliter burette with stand.
12. A 250-milliliter volumetric flask.
13. A 25-milliliter volumetric pipette.
14. A white titration cup.
15. A butter trier for sampling from boxes or tubs.

Supplies:

1. A suitable fat solvent such as petroleum ether or high-test gasoline.
2. Silver nitrate solution prepared by dissolving 29.064 grams of pure silver nitrate crystals in distilled water and making up to 1 liter.
3. A supply of 5 per cent potassium chromate solution in distilled water.
4. A supply of distilled or chlorine-free water.

Sampling Butter. When sampling butter from the churn, it is necessary first to eliminate extraneous moisture by scraping off the top surface of the butter. Ten or twelve portions of 10 to 15 grams each should be taken from points at nearly equally spaced intervals along the full length of the churning. When sampling from a large box or tub, a single trierful should be taken by boring diagonally from the top to the bottom of the tub. About an inch of butter from each end of the trier should be eliminated from the sample. At least two or three packages from each churning should be sampled. When a pound print is to be analyzed, the print should be quartered lengthwise and then all quarters cut transversely in half. Two diagonally opposite eighths are used for the sample.

Preparing the Sample. Samples for analysis should be softened by placing the container in a water bath at a temperature of 90 to 95°F. (32.2 to 35.0°C.). Each sample should be stirred until it possesses a uniform and creamy consistency, resembling that of mayonnaise. Do not melt the sample.

Weighing the Sample. Balance the metal beaker (previously cleaned and dried) on the right-hand pan of the butter balance. The rider on the 20 per cent beam should be placed at the zero mark, and the rider on the 10 per cent beam at the 10 per cent mark. Weigh into the cup exactly 10 grams of butter.

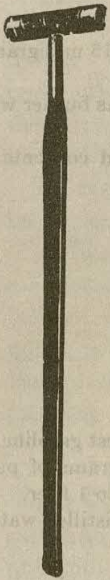


FIG. 92. The butter trier. The trier is used to secure a sample of butter from a given package for examination by a butter judge, or as a sample for analysis. If the entire plug is not required, a sample for analysis may be cut from the plug at various points and the remainder inserted back into the hole from which the plug was removed.

Determining the Moisture Content. The moisture contained in the butter is now evaporated by heating the sample over a flame or on an electric hot plate until the color is a golden-brown and foaming has ceased. After allowing the sample to cool to room tempearture, it is placed on the balance and the moisture loss measured by pushing the weight on the 20 per cent beam from zero to the point of balance. The reading represents the percentage of moisture in the butter sample.

Determining the Fat Content. After the per cent moisture has been determined, the sample should be warmed slightly and 100 milliliters of fat solvent added. The mixture should be thoroughly stirred and then allowed to stand not less than 4 minutes. The solvent containing the dissolved fat is then carefully poured off and the procedure repeated. All but a few drops of solvent should be decanted. After the second extraction the residue, consisting of the salt and curd contained in the butter sample, should be heated at low heat to evaporate the solvent completely. The sample is allowed to cool as in the moisture determination and again placed on the balance. The rider on the 20 per cent beam is returned to zero and the 10-gram weight is removed from the left-hand pan of the balance. Next, the sample is balanced by pushing the rider on the 10 per cent beam toward the zero mark. The reading subtracted from 10 indicates the percentage of salt plus curd contained in the sample. The per cent of salt and curd plus the per cent moisture, subtracted from 100, then gives the per cent fat in the sample.

Determining the Salt Content. The residue remaining from the fat test is rinsed from the beaker and made up to 250 milliliters exactly with warm, chlorine-free water. By means of the volumetric pipette, 25 milliliters of the solution are placed in the titration cup and 2 or 3 drops of potassium chromate solution are added. Standard silver nitrate solution then is added until a flesh or light-orange color develops. The number of milliliters of silver nitrate solution used is equivalent to the percentage of salt in the butter sample.

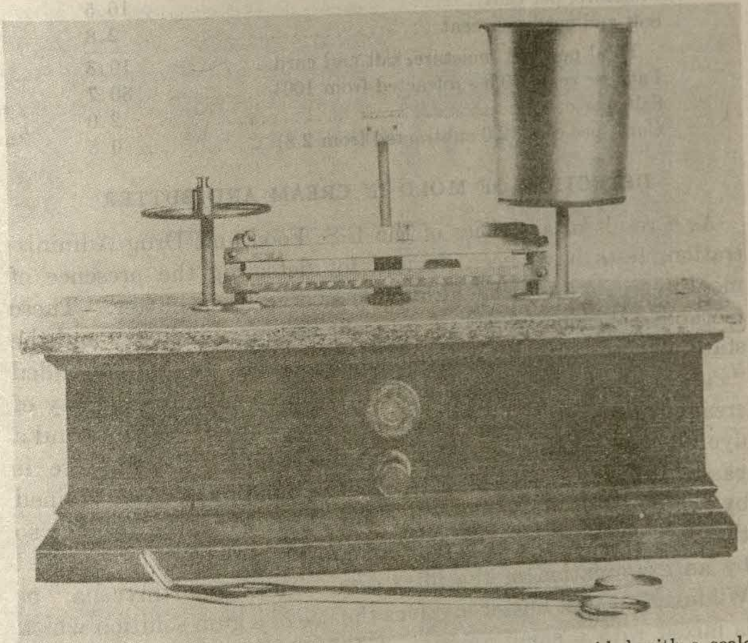


FIG. 93. Butter-moisture scale. A moisture scale is provided with a scale from which the percentage of moisture contained in the sample may be read. The illustration shows also the aluminum cup in which the butter sample is weighed, a 10-gram weight in place on the scale, and tongs with which the cup may be handled.

The salt test may be made directly upon a 10-gram sample of butter. If this is done, enough warm, chlorine-free water should be added so that the bottom of the fat column will be at the 250-milliliter mark on the flask. Twenty-five milliliters of the fat-free solution are then used for the titration as described above.

Determining the Curd Content. The curd content is determined by subtracting the per cent salt from the combined salt and curd percentage as previously determined according to the procedure given above.

Example of Method of Calculation in the Modified Kohman Test

Moisture, per cent	16.5
Salt and curd, per cent	2.8
Total per cent moisture, salt and curd	19.3
Fat, per cent (19.3 subtracted from 100)	80.7
Salt, per cent	2.0
Curd, per cent (2.0 subtracted from 2.8)	0.8

DETECTION OF MOLD IN CREAM AND BUTTER

As a result of activities of the U.S. Food and Drug Administration, tests have been devised for detecting the presence of mold in cream and of mold hyphae or mycelia in butter. These methods are being widely used by the creamery industry and the state or federal law-enforcement agencies. In the so-called "Parson's test" for visible mold in cream, a definite quantity of cream is mixed with a solution containing various reagents and a dye. After heating and stirring the sample, the mixture is passed through a cloth filter disc. The mold hyphae are stained by the dye and are agglutinated into a mass by the reagent so that samples containing various amounts of mold will be detected by an examination of the filter disc. The "mold mycelia" or Wildman's test of butter involves the use of a gum solution which is mixed with a small amount of butter. After the butter has been mixed thoroughly in the warm solution, a portion of the mixture is mounted on a mold-counting slide and examined under the microscope. The relative number of positive fields (those in which mold filaments are visible) in at least 25 microscopic fields determines the rating given the sample. Excessive amounts of mold indicate that the cream was of inferior quality.

DETECTION OF ADDED WATER IN MILK BY FREEZING-POINT DETERMINATION

The freezing point of milk is influenced by the constituents which occur in molecular dispersion or true solution. Since these constituents do not vary greatly, the point at which milk freezes is fairly constant at 13.01°F. (−0.55°C.). Added water in fresh milk may be detected to amounts as low as 3 per cent, by the accurate determination of the freezing point of milk. The determination is made by supercooling milk to a point slightly below the normal freezing point and starting the freezing action by inserting a small crystal of ice into the milk. An accurate thermometer inserted in the milk during the cooling and freezing indicates the temperature at which the milk freezes. The cryoscopic method as embodied in the apparatus designed by Hortvet is the one most frequently used in conducting the test.

The test is used to a limited extent by purchasers of large quantities of milk and in milk-inspection laboratories. The limited use of the test is chiefly due to the skill required in conducting it.

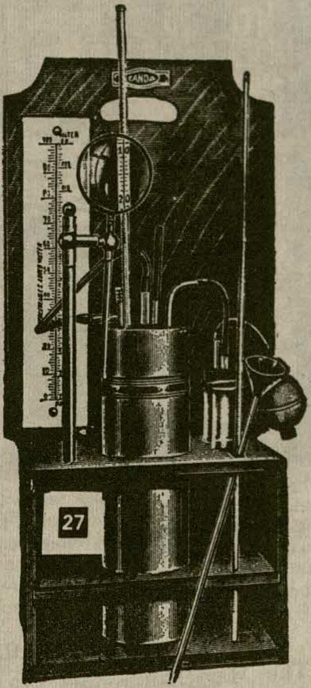


Fig. 94. Hortvet cryoscope. This apparatus is designed to determine the freezing point of milk. It is used primarily in control laboratories when it is desired to determine whether milk has been adulterated with water.

TOTAL-SOLIDS DETERMINATION

It is a common procedure in many manufacturing plants using dairy products, such as ice-cream factories, condensaries, and dry-milk plants, to analyze milk and the finished products for dry matter or "total solids." The "Mojonnier tester" is used frequently for this purpose in these factories and it is also used in making the fat determination by the modified Roese-Gottlieb method. The Mojonnier method of determining the total solids of milk is virtually the same as the official method of the Association of Official Agricultural Chemists. The chief difference lies in the special provisions which are made available in the Mojonnier tester for rapid heating and subsequent cooling of the sample. The procedure consists of weighing a few grams of the product to be analyzed into a flat-bottomed dish and subjecting the sample to heat until all moisture has been driven off. The moisture, or the total dry residue which remains, may be calculated in this way.

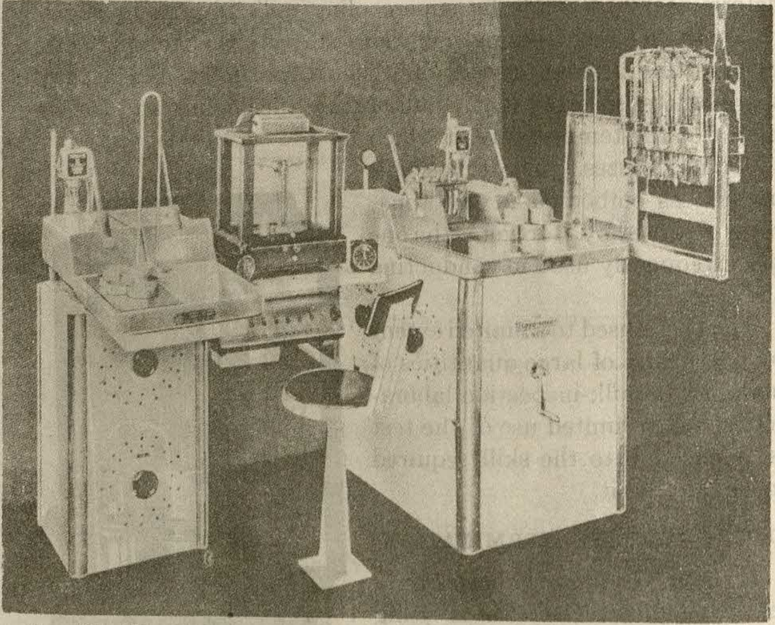


FIG. 95. The Mojonnier tester is a compact apparatus containing all the equipment and reagents necessary for the total-solids analysis and a modified method of conducting the Roese-Gottlieb test. The apparatus is used in large market-milk plants, ice-cream factories, and milk-condensing and milk-drying plants, where a single analysis may represent a large volume of product, and it is important that the analysis be accurate. (*Courtesy of Mojonnier Brothers.*)

THE MARSCHALL RENNET TEST

The Marschall rennet test is used frequently in the cheese factory when it is desired to set milk with rennet under uniform conditions from day to day. The test consists of adding 1 milliliter of rennet to a definite quantity of milk and observing the rate of coagulation. Rennet coagulation of milk is influenced principally by the temperature of the milk, the strength of the rennet extract, and the acidity of the milk. The first two mentioned factors can be controlled, but the acidity of milk may vary from day to day. The rennet test, therefore, serves as an indirect measure of the acidity of milk, since the more acid present in milk, the more quickly the rennet will coagulate the milk.

The Marschall rennet test makes use of a 1-milliliter pipette to measure the rennet extract, a small bottle in which the diluted rennet is placed, a spatula with which to mix the milk, and a special cup to hold the milk. The cup generally is made of graniteware and about 1 quart in capacity. On the inside of the cup is a scale graduated from 0 at the top to 10 at the bottom. A small hole in the bottom of the cup permits the milk to flow out.

The test is operated as follows: 1 milliliter of rennet extract is placed in the small bottle and made up to 20 milliliters with cold water. The cup is filled with milk at from 84 to 86°F. (28.9 to 30°C.) to above the zero mark. The milk is permitted to flow through the small opening in the bottom of the cup. When the surface of the milk reaches the zero mark, the diluted rennet is added, and the milk stirred thoroughly with the spatula until the milk has passed half of one space on the scale.

The flow of the milk eventually is stopped, due to the coagulating action of the rennet. Observation is then made on the scale at the point reached by the surface of the milk. If good results are being secured in the manufacture of cheese with a rennet test of four and the rennet test indicates six, the cheese maker knows that more acid must be permitted to develop before the rennet extract is added to the vat of milk. If the rennet test indicates three spaces, the cheese maker knows that too much acid is present and acts accordingly in conducting the manufacturing process.

THE METHYLENE BLUE REDUCTION TEST FOR QUALITY OF MILK

This test is variously known by several names, such as the "reductase," "methylene blue," and "methylene blue reduction test." It is a test that shows the comparative activity of the bacteria in milk and, for this reason, it is a rough indication of the number of bacteria per milliliter. It is based on the observation that the color imparted to milk by a small amount of methylene blue disappears in a time, the length of which is dependent largely upon the number of microörganisms present if other factors are constant. The change brought about is a chemical reduction of the methylene blue due to the action of the bacteria, apparently by the utilization of the oxygen dissolved in the milk as some believe or due to an enzyme, reductase, produced by organisms. In conducting the test, definite quantities of methylene blue are added to 10 milliliters of milk and the samples held at a uniform temperature (98.6°F. (37°C.)) until the blue color has disappeared. The milk which remains blue the longest is considered to be of the best quality, and a scale of grading different milk samples, on the basis of the time required to reduce a definite quantity of methylene blue, has been worked out.

The same test may be applied to sweet cream by using a more concentrated solution of methylene blue.

Use of the Test. This test finds wide application in certain of the dairy industries. It is particularly adapted to guide the cheese maker in grading the milk delivered to his factory, and compact outfits for use in making the test are on the market. Buyers of milk for condensing also find the test a good one for grading the milk from the individual producers. The reductase test is used to some extent by the buyers of milk for the market-milk trade, and by creameries for grading sweet cream.

THE RESAZURIN TEST

A test similar to the methylene blue reduction test was introduced a few years ago using the indicator resazurin to measure the reducing capacity of milk. A dilute solution of the resazurin is added to 10 milliliters of milk and the samples are held for 1 hour at 37°C. (98.6°F.) in a water bath. If the number of bacteria in milk is large, the color will change from blue to pink to white within the hour of incubation. The degree of color change is in proportion to the number of bacteria present. The cells present in milk may also influence the reduction of resazurin and for that reason the test may also measure physiologically or pathologically abnormal milk.

THE ALCOHOL TEST

When milk contains more than 0.21 per cent acid, or when calcium and magnesium compounds are present in greater than normal amounts, it will coagulate on the addition of alcohol. This fact is the basis of the alcohol test which furnishes a means of judging the quality of milk. Coagulation of milk by alcohol also may be due to several causes other than those mentioned above, among which should be mentioned diseases of the udder, presence of colostrum, and rennin formed by microörganisms.

The widest use of the alcohol test is found in the condensed-milk industry. Difficulties with coagulation of milk during the process of condensing are rather common. Research work has indicated that this trouble may be caused by an excess of calcium and magnesium salts in the milk. The alcohol test, used on fresh milk, along with the acidity test, will usually indicate the milk which is likely to coagulate during processing. If the acidity of the milk is lower than 0.21 per cent, coagulation by alcohol is taken to indicate a salt balance in the milk, which is unfavorable to processing. If such milk cannot be returned, the buyer at least knows that certain precautions in processing are necessary.

Details of the Test. The only reagent needed is a 75 per cent alcohol solution. This is usually prepared from 95 per cent alcohol by mixing with distilled water in the proportion of 79 parts of 95 per cent alcohol to 21 parts of distilled water. Ordinary 6-inch test tubes serve as containers for the tests. Means for supporting these tubes in an upright position should be available, such as test-tube racks, wire baskets, or blocks of wood with holes bored to fit the test tubes. Equal parts of 75 per cent alcohol and milk are placed in a tube, the tube inverted several times with the thumb held tightly over the open end, and then the tube is examined to note any coagulation that may have occurred. If coagulation has occurred, fine particles of curd will be visible on the inside surface of the tube, or the tube will show a very milky layer which would not be visible if no coagulation had occurred. Some experience in interpreting the results of these tests is desirable.

THE FERMENTATION TEST

One test of the quality of milk consists in setting samples of the milk, to be examined at room temperature, in tubes that previously have been boiled in water to render them practically sterile. This is a good means for differentiating between very bad milk and good milk. If the milk does not curdle for a long time, it is usually of good quality and contains few bacteria. If it curdles relatively soon, but forms a smooth curd free from gas pockets and little whey, the milk is of fair quality. If it curdles quickly, forms numerous gas pockets, and clear whey appears, the milk is of very poor quality.

It must be remembered that such a test is very crude, and results of one day may not compare favorably with those of another day because of the varying temperature conditions. A number of milks tested at one time, however, under identical conditions may be compared directly. If milk shows gas fermentation continually, that milk is being produced under filthy conditions, for the most common gas-producing and putrefactive organisms are found in fecal matter and other filth.

TESTS FOR HEATED MILK

Several tests have been devised for determining whether milk has been pasteurized. The tests which have been used are based on the presence in milk of certain enzymes.

Tests Based on Peroxidase. Earlier tests, such as the Storch test and Arnold or Guaiac test, were based upon the destruction of the enzyme, peroxidase, by heat. Peroxidase is destroyed in milk at approximately 176°F. (80°C.) during flash pasteurization (2½ seconds), while it takes about 30 minutes at 161°F. (71.7°C.); therefore, tests involving this enzyme could not be used as a means of checking usual commercial pasteurization procedures in the market-milk industry. They have been used to some extent, however, to check upon the heat-treatment of milk or cream where the higher temperatures are required in processing.

Tests Based on Amylase. A test for pasteurization devised by Leahy involved the detection of amylase, a starch-digesting enzyme, in milk. Although this test seemed more promising than the earlier tests based upon peroxidase, its use has generally been discarded in favor of more accurate methods recently developed.

Tests Based on Phosphatase. A method of detecting inadequate pasteurization of milk and cream known as the "phosphatase test" was introduced by Kay and Graham in 1933. This test, with recent modifications, is now used almost universally by health departments and control laboratories. The test is based on the ability of the enzyme, phosphatase, to liberate phenol from phosphoric-phenyl esters. When milk is heated at 143°F. (61.7°C.) for 30 minutes, most of the enzyme is destroyed, and heating above 145°F. (62.8°C.) for 30 minutes effects complete inactivation. When the milk has been underpasteurized (in temperature or time) or when raw milk has been added to pasteurized milk, the amount of enzyme present can be readily detected by a colorimetric determination of the liberated phenol. The test is sufficiently sensitive to be remarkably reliable.

The phosphatase test is now being applied to chocolate milk, butter, ice cream, and cheese to determine if these products have been manufactured from adequately pasteurized milk or cream.

TO DISTINGUISH BETWEEN BUTTER AND OLEOMARGARINE

The question as to how to distinguish between oleomargarine and true butter frequently arises in the minds of those purchasing butter. It should be clearly understood that it is not possible in all cases to differentiate between the two by simple tests and that carefully conducted chemical analysis of the fat may be necessary if a positive result is required. This can be done only by a competent chemist experienced in the technique of analyzing dairy products and interpreting the results. A simple test which can be used to a limited extent, however, is known as the "household foam test." It consists of heating the suspected sample in a spoon over a slow flame. Oleomargarine boils with a marked noise and considerable sputtering, but produces little or no foam. Butter generally boils with less noise and foams vigorously. Renovated butter acts in the same way as oleomargarine.

NOTE. Detailed directions for making many of the common tests will be found in "Standard Methods for the Examination of Dairy Products" published by the American Public Health Association and the Association of Official Agricultural Chemists. Standard methods for the grading and analysis of dry-milk products are published by the American Dry Milk Institute, Inc.

APPENDIX

METHODS FOR BACTERIOLOGICAL ANALYSIS OF MILK[1]

1. Collection of Samples. Milk should be thoroughly mixed, and sampled with a sterile tube long enough to reach to the bottom of the can or bottle. Each sample should be at least 10 milliliters and should be kept in a tightly stoppered bottle or vial (closure with cotton plugs is not permitted). Samples should be iced, and if plates are not made within 4 hours of the time when the samples were taken, the time elapsing should be reported.

2. Macroscopic Colony Count (Agar Plate Method).

Composition of Medium

	Per cent
Agar (market, not oven-dried)	1.5
Beef extract	0.3
Tryptone	0.5
Glucose	0.1
Distilled water.	

One per cent of skim milk is added just before sterilization.

The preferred reaction of the medium is pH 7.0, but it need not be adjusted if it is between pH 6.6 and pH 7.0. If necessary to adjust the reaction, special attention should be given to the H-ion concentration, making use of the indicator brom thymol blue.

At least two dilutions are usually made in plating: 1 to 100, 1 to 1,000, or 1 to 10,000—unless the quality of the milk is such that the highest or lowest of these is known to be superfluous. In no case are less than two plates made from each sample. Each sample bottle and dilution bottle should be shaken 25 times with an up-and-down motion of about 1 foot, within an interval of 7 seconds. After dilution of the milk, the agar should be poured into the plates within 20 minutes.

Incubation is at 32 or 35°C. for 48 hours.

The plates used for counting should have, if possible, between 30 and 300 colonies each. If there are no plates within these limits, the one having nearest to 300 should be counted. Counting should be done with a lens magnifying 1½ diameters. The exact counts from each plate should be recorded, but not more than two significant left-hand digits should be used in making the final report.

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[1] See "Standard Methods for the Examination of Dairy Products," published by the American Public Health Association, New York, for complete description of methods.

Results should be expressed, not as so many "bacteria per milliliter" of milk; but as "colonies per milliliter," or better as "standard plate count" so much per milliliter. The practice of publishing counts from individual samples of milk showing the quality of a given milk supply is not approved, and a series of samples should be examined before rendering judgment in regard to any milk supply.

3. Direct Microscopic Count of Bacteria (Breed Method).[1] Milk is taken in a capillary pipette or calibrated loop discharging 0.01 milliliter and dried over an area of 1 square centimeter on a microscopic slide. The film should be stained in a methylene blue solution after washing out the fat in xylene and fixing in alcohol. The number of bacteria per milliliter should be estimated by counting those within a given area in a microscopic field, this area having been carefully measured and its ratio to a square centimeter determined. At least 1/10,000 part of a milliliter of milk is to be examined, and if the milk is of high grade, this must be done under favorable conditions for accurate counting. The results should be recorded as "Clump microscopic count per milliliter" or "Individual microscopic count per milliliter."

ROESE-GOTTLIEB METHOD OF FAT DETERMINATION[2]

Transfer 10 grams of sample to Mojonnier fat-extraction flask or Röhrig tube. Add 1.25 milliliters of NH_4OH (2 milliliters if sample is sour) and mix thoroughly. Add 10 milliliters of alcohol and mix well. Add 25 milliliters of ether, stopper with cork or with stopper of synthetic rubber unaffected by usual fat solvents, and shake vigorously 1 minute. Add 25 milliliters of petroleum benzine (redistilled slowly at temperature below 65°C.) and repeat vigorous shaking. Centrifuge Mojonnier flask 20 minutes at about 600 r.p.m. or let it (or Röhrig tube) stand until upper liquid is practically clear. Decant ether solution into suitable flask or metal dish. Wash lip and stopper of extraction flask or tube with mixture of equal parts of the two solvents; add washings to weighing flask or dish. Twice repeat extraction of liquid remaining in flask or tube, using 15 milliliters of each solvent each time. Evaporate solvents on hot plate or steam bath at temperature that affects complete evaporation, but not so high that spattering or vigorous bumping will result. Dry fat in oven at temperature of boiling H_2O to constant weight. Weigh cooled flask or dish, using as counterpoise a duplicate container handled in same manner, and avoid wiping either immediately before weighing. Remove fat completely from container with warm petroleum benzine, dry, and weigh as before. Deduct from total weight. Loss in weight = weight of fat. Correct weight of fat by blank determination on reagents used.

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[1] See "Standard Methods for the Examination of Dairy Products," published by the American Public Health Association, New York, for complete description of methods.

[2] From "Official and Tentative Methods of Analysis," Association of Official Agricultural Chemists, 6th ed., Washington, D.C., 1945.

BABCOCK METHOD OF FAT DETERMINATION[1]

(Official Method of Association of Official Agricultural Chemists)

A. REAGENT

Sulfuric acid. Specific gravity 1.82 to 1.83 at 20°C.

B. APPARATUS

(a) *Standard Babcock Test Bottle for Milk.* 8 per cent 18-gram, 6-inch milk-test bottle, total height 150–165 millimeters (5.9 to 6.5 inches).

The bottom of the bottle shall be flat and the axis of the neck shall be vertical when the bottle stands on a level surface. The charge of milk for the bottle shall be 18 grams.

Bulb. The capacity of the bulb to the junction with the neck shall be not less than 45 cubic centimeters. The shape of the bulb shall be either cylindrical or conical. If cylindrical, the outside diameter shall be between 34 and 36 millimeters; if conical the outside diameter of the base shall be between 31 and 33 millimeters, and the maximum diameter between 35 and 37 millimeters.

Neck. The neck shall be cylindrical and of uniform diameter from at least 5 millimeters below the lowest graduation mark to at least 5 millimeters above the highest. The top of the neck shall be flared to a diameter of not less than 10 millimeters. The graduated portion of the neck shall have a length of not less than 63.5 millimeters. The total per cent graduation shall be 8. The graduations shall represent whole per cent, 0.5 per cent, and 0.1 per cent, respectively, from 0.0 to 8.0 per cent. The tenths per cent graduations shall not be less than 3 millimeters in length; the 0.5 per cent graduations shall not be less than 4 millimeters in length and shall project 1 millimeter to the left; and the whole per cent graduations shall extend at least halfway around the neck to the right and shall project at least 2 millimeters to the left of the tenths per cent graduations. Each whole per cent graduation shall be numbered, the number being placed to the left of the scale. The capacity of the neck for each whole per cent on the scale shall be 0.20 cubic centimeter. The maximum error of the total graduation or any part thereof shall not exceed the volume of the smallest unit of the graduation.

Each bottle shall be so constructed as to withstand the stress to which it will be subjected in the centrifuge.

(a_1) *Testing.* The mercury-and-cork, alcohol-and-burette, and alcohol-and-brass-plunger methods may be employed for the rapid testing of the bottles, but the accuracy of any questionable bottle shall be determined by calibration with mercury (13.5471 grams of clean dry mercury at 20° to be equal to 5 per cent on the scale of an 18-gram bottle and 10 per cent on the scale of a 9-gram bottle), the bottle being previously filled to zero with mercury.

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[1] From "Standard Methods for the Examination of Dairy Products," American Public Health Association, New York.

(*b*) *Pipette.* The standard milk pipette shall conform to the following specifications:

Total length, not more than 330 millimeters.

Outside diameter of suction tube, 6–8 millimeters.

Length of suction tube, 130 millimeters.

Outside diameter of delivery tube, 4.5–5.5 millimeters.

Length of delivery tube, 100–120 millimeters.

Distance of graduation mark above bulb, 15–45 millimeters.

Nozzle, straight.

Graduation, to contain 17.6 cubic centimeters of H_2O at 20° when the bottom of the meniscus coincides with the mark on the suction tube.

Delivery in 5–8 seconds.

The maximum error in the graduation shall not exceed 0.05 cubic centimeter.

The pipette is to be marked "Holds 17.6 c.c."

(*b_1*) *Testing.* The pipette shall be tested by measuring from a burette the volume of H_2O (at 20°) that it holds up to the graduation mark.

(*c*) *Acid Measure.* The device employed to measure H_2SO_4, whether a graduated cylinder or a pipette attached to a Swedish acid bottle, shall be graduated to deliver 17.5 cubic centimeters.

(*d*) *Centrifuge or "Tester."* The standard centrifuge, however driven, shall be constructed throughout and so mounted as to be capable, when filled to capacity, of rotating at the necessary speed with a minimum of vibration and without liability of causing injury or accident. It shall be heated, electrically or otherwise, to a temperature of at least 55° during the process of centrifugalizing. It shall be provided with a speed indicator, permanently attached, if possible. The proper rate of rotation may be ascertained by reference to the table below. By "diameter of wheel" is meant the distance between the inside bottoms of opposite cups measured through the center of rotation of the centrifuge wheel while the cups are horizontally extended.

Diameter of wheel, in inches........	10	12	14	16	18	20	22	24
Number revolutions per minute.....	1,074	980	909	848	800	759	724	693

(*e*) *Dividers or Calipers.* For measuring the fat column.

(*f*) *Water Bath for Test Bottles.* Provided with a thermometer and a device for maintaining a temperature of 55 to 60°.

MILK PRODUCER-DISTRIBUTOR INSPECTION FORM

Form 8976-A
FEDERAL SECURITY AGENCY
PUBLIC HEALTH SERVICE
Rev. Dec. 1944

Budget Bureau No. 68-R079.
Expires 10-31-47.

GALLONS SOLD DAILY IN COMMUNITY

Whole milk...... ....
Buttermilk...... ....
Cream.......... ....
TOTAL...... ....

....
(City, county, or district)

NAME.......................... LOCATION.......................

SIR: An inspection of your dairy has this day been made and you are notified of the defects marked below with a cross (×). Violation of the same item on two successive inspections calls for immediate degrading.

Item No.[1]

COWS

(1) *Tuberculosis and other diseases.*—Tuberculin test annually except in modified accredited counties ( ), abortion test annually (effective...................., 19...), except in modified accredited counties (for calfhood vaccination see Code) ([2]), evidence of both tests on file ( ), other tests as required ( ), no cows with extensive induration of udder ( ), no cows giving abnormal milk ( ).. ( )

DAIRY BARN

(2) *Lighting, milking barn.*—Adequate light openings ( ), windows clean ( ), adequate artificial light for night milking ( )..... ( )

(3) *Air space and ventilation.*—Well ventilated ( ), no overcrowding ( ).. ( )

(4*a*) *Floor construction, milking barn.*—Floors and gutters, concrete or other impervious and easily cleaned material in good repair ( ), graded ( ).. ( )

(4*b*) *Floor cleanliness, milking barn.*—No accumulations beyond one milking ( ), no horses, pigs, fowl, calves, etc. ( ).......... ( )

(5) *Walls and ceilings.*—Painted biennially or white-washed annually or other satisfactory finish ( ), clean and in good repair ( ), ceiling tight if feedstuffs over ( ), feed-room partition dust-tight with door ( ).. ( )

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[1] Item numbers correspond to item numbers for Grade A raw milk in 1939 edition (as amended Dec. 3, 1942) of United States Public Health Service Milk Ordinance and Code, to which please refer. [2] Not required for Grade B raw. All other Grade B raw requirements (except bacterial standard) are the same as for Grade A raw.

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C.
Price, 40 cents per pad of 100
U. S. GOVERNMENT PRINTING OFFICE 16—43054-1

Item No.

(6a) ***Cow yard, grading and draining.***—Graded ( ), drained ( ), no pooled wastes ( )................................ ( )

(6b) *Cow yard, cleanliness.*—Clean ( ), no swine ( )............. ( )

(7) *Manure disposal.*—Stored inaccessible to cows and, during fly season: (*a*) Spread upon fields, or (*b*) piled not more than 4 days and then spread, or (*c*) stored not more than 7 days in impervious bin or curbed platform and then spread, or (*d*) stored in tight, screened, and trapped manure shed, or (*e*) fly breeding minimized by other approved methods............ ( )

MILK HOUSE

(8a) *Floors.*—Smooth concrete or other impervious material ( ), graded to drain ( )....................................... ( )

(8b) *Walls and ceilings.*—Smooth dressed lumber, sheet metal, or plasterboard, well painted with washable paint; hollow tile, cement blocks, bricks, concrete, or cement plaster, surfaces and joints smooth.. ( )

(8c) *Lighting and ventilation.*—Effective window area at least 10 percent of floor area ( ), adequate artificial lighting (see Code) ( ), adequate ventilation ( ), doors and windows closed during dusty weather ( )........................... ( )

(8d) *Screening.*—All openings effectively screened and doors open outward and self-closing, unless flies otherwise kept out.......... ( )

(8e) *Miscellaneous requirements.*—Used for milk purposes only, except by permission ( ), milk house operations not conducted elsewhere ( ), no opening into living quarters or stable ( ), piped water ( ), wastes properly disposed of ( ), processes partitioned ( ), 2-compartment stationary wash and rinse vats, 3 compartments if chlorine used ( ), adequate water-heating facilities ( )................................ ( )

(9) *Cleanliness and flies.*—Floors, walls, windows, shelves, tables, and equipment clean ( ), no trash or unnecessary articles ( ), all necessary fly-control methods ( )....................... ( )

TOILET

(10) *Toilet.*—Conveniently located ( ), constructed and operated according to Code ( ), no evidence of defecation or urination about premises ( )...................................... ( )

WATER SUPPLY

(11) *Water supply.*—Easily accessible ( ), adequate ( ), no surface or cistern water unless approved ( ), safe, sanitary quality (see Code) ( ).. ( )

UTENSILS

(12) *Construction.*—Smooth heavy-gage material ( ), corrosion-proof surface, no agateware ( ), easily cleanable shape ( ), joints soldered flush ( ), good repair ( ), no woven-wire cloth ( ).

Item No.

milk pails small-mouth design ( ), approved single-service containers ( ).. ( )

(13) *Cleaning.*—Cleaned after each usage ( ), must look and feel clean ( ).. ( )

(14) *Bactericidal treatment.*—Steam cabinet 170°F. for 15 minutes or 200°F. for 5 minutes, or steam jet 1 minute, or immersed in standard chlorine or 170°F. water for 2 minutes, or flow of 170°F. water at outlet for 5 minutes or standard chlorine for 2 minutes, or hot-air cabinet 180°F. for 20 minutes ( ), cabinets have thermometer in coldest zone ( )............. ( )

(15) *Storage.*—Left in treating chamber until used or stored inverted on racks or in clean crates above floor in milk house ( ), cotton disks in original package in cabinet until used ( ).... ( )

(16) *Handling.*—After bactericidal treatment no handling of surfaces to which milk is exposed.................................. ( )

MILKING

(17) *Udders and teats.*—Clean ( ), rinsed with standard chlorine solution at time of milking ( ), abnormal milk excluded ( ).. ( )

(18) *Flanks.*—Flanks, bellies, and tails free from visible dirt at time of milking ( ), brushing completed before milking begun ( ).. ( )

(19) *Milkers' hands.*—Clean ( ), rinsed in standard chlorine solution just before milking each cow ( ), dry while milking ( ), hand-washing facilities including soap, water, and individual clean towels convenient to milking barn ( )........................ ( )

(20) *Clothing.*—Clean outer garments............................ ( )

(21) *Milk stools.*—Clean, not padded ( ), stored above floor ( ).... ( )

(22) *Removal of milk.*—Immediate removal to milk house or straining room ( ), no straining in barn ( ), can covered, protected from manure and splash ( )........................ ( )

(23) *Cooling.*—Milk cooled immediately after milking completed to 50°F. or less and so maintained until delivery to consumer.... ( )

BOTTLING AND CAPPING

(24) *Bottling and capping.*—Sanitary bottle filler ( ), no hand capping ( ), caps kept in sanitary tubes in clean, dry place until used ( ), first cap discarded ( )........................ ( )

EMPLOYEES

(25) *Personnel, health.*—Required examinations and tests ( ), rejected persons not employed ( ), no person with infected wound or lesion ( )........................ ( )

MISCELLANEOUS

(26) *Vehicles.*—Clean ( ), permanent top and permanent or roll-down sides and back ( ), no contaminating substances transported ( ), distributor's name shown ( ). *Premises.*—Surroundings kept neat and clean ( )........................ ( )

Date.................... ...., *Inspector.*

SPECIFIC GRAVITY AND WEIGHT PER GALLON OF SKIM MILK, MILK,[1] AND CREAM[2]

Percentage of fat (by weight)	Specific gravity, 20°/4°C.	Specific gravity, 10°/4°C.	Pounds per gallon at 20°C. (68°F.)	Pounds per gallon at 10°C. (50°F.)
0.025	1.035	1.037	8.63	8.65
10	1.023	1.027	8.53	8.56
11	1.022	1.026	8.52	8.55
12	1.020	1.025	8.50	8.54
13	1.019	1.024	8.49	8.54
14	1.017	1.023	8.48	8.53
15	1.016	1.022	8.47	8.52
16	1.015	1.021	8.46	8.51
17	1.014	1.020	8.45	8.50
18	1.013	1.019	8.44	8.49
19	1.012	1.018	8.44	8.49
20	1.011	1.017	8.43	8.48
21	1.010	1.017	8.42	8.48
22	1.009	1.016	8.41	8.47
23	1.008	1.015	8.40	8.46
24	1.007	1.014	8.40	8.46
25	1.007	1.014	8.39	8.45
26	1.006	1.013	8.39	8.45
27	1.005	1.012	8.38	8.44
28	1.004	1.012	8.37	8.44
29	1.003	1.011	8.36	8.43
30	1.002	1.011	8.36	8.43
31	1.001	1.010	8.34	8.42
32	1.000	1.010	8.34	8.42
33	0.999	1.009	8.33	8.41
34	0.998	1.008	8.32	8.40
35	0.998	1.008	8.31	8.40
36	0.997	1.007	8.31	8.40
37	0.996	1.007	8.30	8.39
38	0.995	1.006	8.30	8.39
39	0.994	1.005	8.29	8.38
40	0.993	1.005	8.28	8.38

[1] The weight of milk containing from 3.5 to 5 per cent of milk fat for all practical purposes may be figured at 8.6 pounds per gallon or 2.15 pounds per quart.

[2] Reproduced in part from p. 42, *Circ.* 19, U.S. Bureau of Standards, Washington, D.C., 1924.

AUTHORS' NOTE: The specific gravities here presented were based on work with mixed herd milk and should not be translated as referring to milk of individual cows.

Specific gravity 20°/4°C. means the specific gravity at 20°C. (68°F.) in terms of water at its maximum density as unity, and specific gravity 10°/4°C. means the specific gravity at 10°C. (50°F.) in terms of the same unit. These specific-gravity values are numerically the same as density at 20 and 10°C., respectively, in grams per milliliter.

NOTE: The specific gravity at 20°/20°C. (68°/68°F.) corresponding to any percentage of fat can be obtained by dividing the specific gravity at 20°/4°C. by the density of water at 20°C. (0.9982343).

STANDARD UNITS OF MEASURE AND WEIGHT

Unit of Length

A meter (m.) is taken from the international prototype meter at the International Bureau of Weights and Measures; at 32°F. (0°C.) = 39.37 inches (in.) = 3.280833 feet (ft.) = 100 centimeters (cm.).

A centimeter (cm.) = 10 millimeters (mm.) = 10,000 microns (μ) = 0.3937 inch (in.).

A millimeter (mm.) = 1,000 microns (μ) = 0.03937 inch (in.).

A micron (μ) = 1,000 milli-microns (mμ) = 3.937×10^{-5} inch (in.).

A milli-micron (mμ) = 0.001 micron.

A foot (ft.) = 0.3048006 meter (m.) = 30.48006 centimeters (cm.) = 12 inches (in.).

An inch (in.) = 2.539998 centimeters (cm.) = 25.39998 millimeters (mm.) = 25,399.98 microns (μ).

Unit of Capacity

A liter (l.) is the volume occupied by the mass of 1 kilogram of pure water at 4°C. under barometric pressure of 760 millimeters = 0.26417762 gallon (gal.) = 0.035316 cubic foot (cu. ft.) = 61.025 cubic inches (cu. in.) = 1.05671 quarts (qt.) = 2.1134 pints (pt.) = 33.8147 fluid ounces (oz. fl.) = 1000.027 cubic centimeters (cc.) = 1,000 milliliters (ml.).

A milliliter (ml.) = 0.0338147 fluid ounce (oz. fl.) = 0.001 liter (l.) = 1.000027 cubic centimeter (cc.).

A cubic centimeter (cc. or cm.^{3}) = 0.0010567 quart (qt.) = 0.033814 fluid ounce (oz. fl.) = 0.99997 milliliter (ml.).

A gallon U.S. (gal.) = 231 cubic inches (cu. in.) = 3.785332 liters (l.) = 3785.4 cubic centimeters (cc.) = 3785.332 milliliters (ml.).

A quart U.S. (qt.) = 57.749 cubic inches (cu. in.) = 0.94633 liter (l.) = 946.358 cubic centimeters (cc.) = 946.333 milliliters (ml.).

A pint U.S. (pt.) = 16 fluid ounces (oz. fl.) = 0.473167 liter (l.) = 473.179 cubic centimeters (cc.) = 473.167 milliliters (ml.).

A fluid ounce (oz. fl.) = 0.0625 pint (pt.) = 0.0295729 liter (l.) = 29.5737 cubic centimeters (cc.) = 29.5729 milliliters (ml.).

Unit of Weight or Mass

A kilogram (kg.) is taken from the international prototype kilogram at the International Bureau of Weights and Measures = 2.2046223 pounds (avoirdupois) (lb. av.) = 35.273957 ounces (avoirdupois) (oz. av.) = 1,000 grams (g.).

A gram (g.) = 0.0352739 ounce (avoirdupois) (oz. av.) = 1,000 milligrams (mg.).

A milligram (mg.) = 3.52739×10^{-5} ounce (avoirdupois) (oz. av.) = 0.001 gram (g.) = 1,000 micrograms (μg. or γ).

A microgram (μg. or γ) = 0.001 milligram (mg.).

A pound (avoirdupois) (lb. av.) = 16 ounces (avoirdupois) (oz. av.) = 0.4535924 kilogram (kg.) = 453.5924 grams (g.).

An ounce (avoirdupois) (oz. av.) = 0.0625 pound (avoirdupois) (lb. av.) = 28.349527 grams (g.).

TABLE FOR CALCULATING TOTAL SOLIDS IN MILK FROM SPECIFIC GRAVITY AND FAT PERCENTAGE

Per Cent Total Solids

	Lactometer reading at 60°F. (15.6°C.) (Quevenne degrees)										
Percentage of fat	26	27	28	29	30	31	32	33	34	35	36
3.00	10.10	10.35	10.60	10.85	11.10	11.36	11.61	11.86	12.11	12.36	12.61
3.05	10.16	10.41	10.66	10.91	11.17	11.42	11.67	11.92	12.17	12.42	12.68
3.10	10.22	10.47	10.72	10.97	11.23	11.48	11.73	11.98	12.23	12.48	12.74
3.15	10.28	10.53	10.78	11.03	11.29	11.54	11.79	12.04	12.29	12.55	12.80
3.20	10.34	10.59	10.84	11.09	11.35	11.60	11.85	12.10	12.35	12.61	12.86
3.25	10.40	10.65	10.90	11.16	11.41	11.66	11.91	12.16	12.42	12.67	12.92
3.30	10.46	10.71	10.96	11.22	11.47	11.72	11.97	12.22	12.48	12.73	12.98
3.35	10.52	10.77	11.03	11.29	11.53	11.78	12.03	12.28	12.54	12.79	13.04
3.40	10.58	10.83	11.09	11.34	11.59	11.84	12.09	12.34	12.60	12.85	13.10
3.45	10.64	10.89	11.15	11.40	11.65	11.90	12.15	12.40	12.66	12.91	13.16
3.50	10.70	10.95	11.21	11.46	11.71	11.96	12.21	12.46	12.72	12.97	13.22
3.55	10.76	11.02	11.27	11.52	11.77	12.02	12.27	12.52	12.78	13.03	13.28
3.60	10.82	11.08	11.33	11.58	11.83	12.08	12.33	12.58	12.84	13.09	13.34
3.65	10.88	11.14	11.39	11.64	11.89	12.14	12.39	12.64	12.90	13.15	13.40
3.70	10.94	11.20	11.45	11.70	11.95	12.20	12.45	12.70	12.96	13.21	13.46
3.75	11.00	11.26	11.51	11.76	12.01	12.26	12.51	12.76	13.02	13.27	13.52
3.80	11.06	11.32	11.57	11.82	12.07	12.32	12.57	12.82	13.08	13.33	13.58
3.85	11.12	11.38	11.63	11.88	12.13	12.38	12.63	12.88	13.14	13.39	13.64
3.90	11.18	11.44	11.69	11.94	12.19	12.44	12.69	12.94	13.20	13.45	13.70
3.95	11.24	11.50	11.75	12.00	12.25	12.50	12.75	13.00	13.26	13.51	13.77
4.00	11.30	11.56	11.81	12.06	12.31	12.56	12.81	13.06	13.32	13.57	13.83
4.05	11.36	11.62	11.87	12.12	12.37	12.62	12.87	13.12	13.38	13.63	13.89
4.10	11.42	11.68	11.93	12.18	12.43	12.68	12.93	13.18	13.44	13.69	13.95
4.15	11.48	11.74	11.99	12.24	12.49	12.74	12.99	13.25	13.50	13.76	14.01
4.20	11.54	11.80	12.05	12.30	12.55	12.80	13.05	13.31	13.56	13.82	14.07
4.25	11.60	11.86	12.11	12.36	12.61	12.86	13.12	13.37	13.62	13.88	14.13
4.30	11.66	11.92	12.17	12.42	12.67	12.92	13.18	13.43	13.68	13.94	14.19
4.35	11.72	11.98	12.23	12.48	12.73	12.98	13.24	13.49	13.74	14.00	14.25
4.40	11.78	12.04	12.29	12.54	12.79	13.04	13.30	13.55	13.80	14.06	14.31
4.45	11.84	12.10	12.35	12.60	12.85	13.10	13.36	13.61	13.86	14.12	14.37
4.50	11.90	12.16	12.41	12.66	12.91	13.16	13.42	13.67	13.92	14.18	14.43
4.55	11.97	12.22	12.47	12.72	12.97	13.22	13.48	13.73	13.98	14.24	14.49
4.60	12.03	12.28	12.53	12.78	13.03	13.28	13.54	13.79	14.04	14.30	14.55
4.65	12.09	12.34	12.59	12.84	13.09	13.34	13.60	13.85	14.10	14.36	14.61
4.70	12.15	12.40	12.65	12.90	13.15	13.40	13.66	13.91	14.16	14.42	14.67
4.75	12.21	12.46	12.71	12.96	13.21	13.46	13.72	13.97	14.22	14.48	14.73
4.80	12.27	12.52	12.77	13.02	13.27	13.52	13.78	14.03	14.28	14.54	14.79
4.85	12.33	12.58	12.83	13.08	13.33	13.58	13.84	14.09	14.34	14.60	14.85
4.90	12.39	12.64	12.89	13.14	13.39	13.64	13.90	14.15	14.40	14.66	14.91
4.95	12.45	12.70	12.95	13.20	13.45	13.70	13.96	14.21	14.46	14.72	14.97
5.00	12.51	12.76	13.01	13.26	13.51	13.76	14.02	14.27	14.52	14.78	15.03

A Table for Determining the Total Solids of Sweet Buttermilk from the Lactometer Reading[1]

Lactometer reading	Total solids, per cent	Lactometer reading	Total solids, per cent
20.0	5.40	30.0	8.01
20.5	5.53	30.5	8.14
21.0	5.66	31.0	8.27
21.5	5.79	31.5	8.40
22.0	5.92	32.0	8.53
22.5	6.05	32.5	8.66
23.0	6.18	33.0	8.78
23.5	6.31	33.5	8.91
24.0	6.45	34.0	9.04
24.5	6.57	34.5	9.17
25.0	6.71	35.0	9.30
25.5	6.84	35.5	9.43
26.0	6.97	36.0	9.56
26.5	7.10	36.5	9.69
27.0	7.23	37.0	9.82
27.5	7.36	37.5	9.94
28.0	7.49	38.0	10.07
28.5	7.62	38.5	10.20
		39.0	10.33
29.0	7.75	39.5	10.45
		40.0	10.62
29.5	7.88	40.5	10.71

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[1] Anderson, Albin E., *Some of the Factors Influencing the Composition of Buttermilk*, Master's Thesis, University of Minnesota, 1932.

TEMPERATURE CONVERSION TABLE

Fahrenheit to Centigrade

(Values in body of table given in degrees Centigrade the temperature indicated in degrees Fahrenheit at top and side)

Temperatures *below* 0°F.

Temperature degrees Fahrenheit	0	1	2	3	4	5	6	7	8	9
0	−17.78	−18.33	−18.89	−19.44	−20.00	−20.56	−21.11	−21.67	−22.22	−22.78
−10	−23.33	−23.89	−24.44	−25.00	−25.56	−26.11	−26.67	−27.22	−27.78	−28.33
−20	−28.89	−29.44	−30.00	−30.56	−31.11	−31.67	−32.22	−32.78	−33.33	−33.89
−30	−34.44	−35.00	−35.56	−36.11	−36.67	−37.22	−37.78	−38.33	−38.89	−39.44

Temperatures *above* 0°F.

	0	1	2	3	4	5	6	7	8	9
0	−17.78	−17.22	−16.67	−16.11	−15.56	−15.00	−14.44	−13.89	−13.33	−12.78
+10	−12.22	−11.67	−11.11	−10.56	−10.00	− 9.44	− 8.89	− 8.33	− 7.78	− 7.22
20	− 6.67	− 6.11	− 5.56	− 5.00	− 4.44	− 3.89	− 3.33	− 2.78	− 2.22	− 1.67
30	− 1.11	− 0.56	0.00	+ 0.56	+ 1.11	+ 1.67	+ 2.22	+ 2.78	+ 3.33	+ 3.89
40	+ 4.44	5.00	5.56	6.11	6.67	7.22	7.78	8.33	8.89	9.44
50	10.00	10.56	11.11	11.67	12.22	12.78	13.33	13.89	14.44	15.00
60	15.56	16.11	16.67	17.22	17.78	18.33	18.89	19.44	20.00	20.56
70	21.11	21.67	22.22	22.78	23.33	23.89	24.44	25.00	25.56	26.11
80	26.67	27.22	27.78	28.33	28.89	29.44	30.00	30.56	31.11	31.67
90	32.22	32.78	33.33	33.89	34.44	35.00	35.56	36.11	36.67	37.22

100	37.78	38.33	38.89	39.44	40.00	40.56	41.11	41.67	42.22	42.78
110	43.33	43.89	44.44	45.00	45.56	46.11	46.67	47.22	47.78	48.33
120	48.89	49.44	50.00	50.56	51.11	51.67	52.22	52.78	53.33	53.89
130	54.44	55.00	55.56	56.11	56.67	57.22	57.78	58.33	58.89	59.44
140	60.00	60.56	61.11	61.67	62.22	62.78	63.33	63.89	64.44	65.00
150	65.56	66.11	66.67	67.22	67.78	68.33	68.89	69.44	70.00	70.56
160	71.11	71.67	72.22	72.78	73.33	73.89	74.44	75.00	75.56	76.11
170	76.67	77.22	77.78	78.33	78.89	79.44	80.00	80.56	81.11	81.67
180	82.22	82.78	83.33	83.89	84.44	85.00	85.56	86.11	86.67	87.22
190	87.78	88.33	88.89	89.44	90.00	90.56	91.11	91.67	92.22	92.78
200	93.33	93.89	94.44	95.00	95.56	96.11	96.67	97.22	97.78	98.33
210	98.89	99.44	100.00	100.56	101.11	101.67	102.22	102.78	103.33	103.89
220	104.44	105.00	105.56	106.11	106.67	107.22	107.78	108.33	108.89	109.44
230	110.00	110.56	111.11	111.67	112.22	112.78	113.33	113.89	114.44	115.00
240	115.56	116.11	116.67	117.22	117.78	118.33	118.89	119.44	120.00	120.56
250	121.11	121.67	122.22	122.78	123.33	123.89	124.44	125.00	125.56	126.11

For °F.......	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
interpolation °C.......	0.06	0.11	0.17	0.22	0.28	0.33	0.39	0.44	0.50	0.56

A TABLE FOR DETERMINING THE TOTAL SOLIDS OF SOUR-CREAM BUTTERMILK FROM THE LACTOMETER READING[1]

Lactometer reading	Total solids, per cent	Lactometer reading	Total solids, per cent
20.0	5.11	30.5	7.85
20.5	5.24	31.0	7.98
21.0	5.37	31.5	8.11
21.5	5.50	32.0	8.24
22.0	5.63	32.5	8.37
22.5	5.76	33.0	8.49
23.0	5.89	33.5	8.62
23.5	6.02	34.0	8.75
24.0	6.16	34.5	8.88
24.5	6.29	35.0	9.01
25.0	6.42	35.5	9.14
25.5	6.55	36.0	9.26
26.0	6.68	36.5	9.40
26.5	6.81	37.0	9.53
27.0	6.94	37.5	9.65
27.5	7.07	38.0	9.78
28.0	7.20	38.5	9.91
28.5	7.33	39.0	10.04
29.0	7.46	39.5	10.16
29.5	7.59	40.0	10.33
30.0	7.72	40.5	10.42

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[1] Anderson, Albin E., *Some of the Factors Influencing the Composition of Buttermilk*, Master's Thesis, University of Minnesota, 1932.

MOLECULAR WEIGHTS OF ACIDS, BASES, AND SALTS AND QUANTITIES NECESSARY FOR TENTH-NORMAL SOLUTIONS

Substance	Formula	Molecular weight	Number of grams per liter for N/10 solution
Calcium hydroxide	$Ca(OH)_2$	74.08	3.704
Calcium oxide	CaO	56.07	2.804
Hydrochloric acid	HCl	36.47	3.647
Lactic acid	$C_3H_6O_3$	90.06	9.006
Magnesium oxide	MgO	40.32	2.016
Potassium hydroxide	KOH	56.11	5.611
Silver nitrate	$AgNO_3$	169.89	16.989
Sodium bicarbonate	$NaHCO_3$	84.01	8.401
Sodium carbonate	Na_2CO_3	106.01	5.301
Sodium chloride	$NaCl$	58.46	5.846
Sodium hydroxide	$NaOH$	40.01	4.001

DAIRY PRODUCTS: PER CAPITA CONSUMPTION, PRIMARY DISTRIBUTION WEIGHT 1910–1949[1]

Year	Total milk[2]	Fluid milk and cream[3]	Cheese[4]	Evaporated milk[5]	Condensed milk[5]	Dry whole milk	Dry skim milk	Ice cream (product weight)	Butter
1910–14*	748	335	4.2	2.1	5.1	0.02	[6]	2.6	17.2
1915–19*	731	339	4.0	4.4	5.3	0.05	[6]	5.3	15.7
1920–24*	766	349	4.3	8.3	2.2	0.04	0.3	7.4	16.7
1925–29*	800	348	4.5	9.8	2.2	0.09	0.7	9.4	17.8
1930–34*	820	346	4.5	12.1	1.7	0.09	1.4	7.0	17.9
1935–39*	801	340	5.5	15.0	1.6	0.12	1.9	9.5	16.7
1940	821	343	6.0	17.4	1.8	0.14	2.2	11.3	16.9
1941	808	352	5.9	16.8	1.7	0.16	2.5	13.5	16.0
1942	839	371	6.4	16.4	1.9	0.20	2.5	15.8	15.8
1943	760	394	4.9	17.1	1.7	0.39	2.1	12.2	11.8
1944	773	411	4.8	13.7	1.9	0.34	1.5	12.5	11.9
1940–44*	800	374	5.6	16.3	1.8	0.25	2.2	13.1	14.5
1945	803	432	6.6	16.2	2.0	0.37	2.0	13.1	10.9
1946	813	423	6.6	17.0	1.5	0.51	3.2	22.5	10.5
1947	794	398	6.9	18.2	2.2	0.45	2.9	19.3	11.2
1948	750	387	6.8	18.7	1.9	0.31	3.2	17.1	10.0
1949[7]	742	375	7.1	18.3	2.0	[6]	3.3	16.0	10.3
1945–49*	780	403	6.8	17.7	1.9	[6]	2.9	17.6	10.6

[1] Civilian consumption only, 1941–48. Data for 1948 preliminary.

[2] Whole-milk equivalent on a fat-solids basis.

[3] Includes cream in terms of whole-milk equivalents. Farm weight for farm consumption, distribution weight for non-farm.

[4] Whole- and part-whole milk cheese, excludes full-skim, Cottage, Pot, and Baker's cheese.

[5] Case and bulk goods, unskimmed only.

[6] Not available.

[7] Preliminary.

* Average.

SOURCE: Compiled from "Consumption of Food in the United States, 1909–48," *Misc. Pub.* No. 691, Bureau of Agricultural Economics, U.S. Department of Agriculture, Washington, D.C., August, 1949.

MARKET GRADES OF CREAMERY BUTTER

As Prepared by the U.S. Department of Agriculture[1]

U.S. Grade AA or U.S. 93-score butter shall possess a fine, highly pleasing flavor. It may possess a slightly normal feed or a definitely cooked flavor. It is made from sweet cream or cream of low natural acid to which a culture (starter) may or may not have been added. The permitted total defects in body, color, and salt are limited to one-half (½).

U.S. Grade A or U.S. 92-score butter shall possess a pleasing and desirable flavor. It may possess any of the following flavors to a slight degree: coarse-acid, smothered, flat, heated (summer defect), bitter, aged (butter), and storage, or a normal feed and cooked flavor of a definite degree. The permitted total defects in body, color, and salt are limited to one-half (½) unless the flavor classification permits these defects to exceed one-half (½). Butter that has a flavor classification of AA and total defects in body, color, and salt which exceed one-half (½) but do not exceed one and one-half (1½) shall be U.S. Grade A or U.S. 92 score.

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[1] *Federal Register*, Vol. 8, No. 22, Washington, D.C., February 2, 1943.

U.S. Grade B or U.S. 90-score butter may possess any of the following flavors to a slight degree: Weedy, musty, rape, cabbage, turnip, and woody or any of the following flavors to a definite degree: old-cream, coarse-acid-cream, acidy, utensil, scorched, neutralizer, storage, aged (butter), greasy, and bitter. The permitted total defects in body, color, and salt are limited to a total of one-half (½) unless the flavor classification permits these defects to exceed one-half (½). Butter that has a flavor classification of AA and total defects in body, color, and salt which exceed one-half (½) but do not exceed two and one-half (2½) shall be U.S. Grade B or U.S. 90 score. Butter that has a flavor classification of A and total defects in body, color, and salt which exceed one-half (½) but do not exceed one and one-half (1½) shall be U.S. Grade B or U.S. 90 score.

U.S. Grade C or U.S. 89-score butter may possess any of the following flavors to a slight degree: obnoxious weeds and onion or garlic or any of the following flavors of a definite degree: scorched-neutralizer, sour, fruity, yeasty cheesy, alkaline, oily, metallic, cabbage, turnip, rape, weedy, musty, stale, and barny. The permitted defects in body, color, and salt are limited to a total of one and one-half (1½) unless the flavor classification permits these defects to exceed one and one-half (1½). Butter that has a flavor classification of A and total defects in body, color, and salt which exceed one and one-half (1½) but do not exceed two and one-half (2½) shall be U.S. Grade C or U.S. 89 score. Butter that has a flavor classification of B and total defects in body, color, and salt which exceed one-half (½) but do not exceed one and one-half (1½) shall be U.S. Grade C or U.S. 89 score.

U.S. Cooking-grade butter may possess any of the following flavors of a definite degree: obnoxious weeds, onion or garlic, and fishy; or any of the following flavors of a pronounced degree: yeasty, fruity, cheesy, alkaline, and stale. Defects in body, color, and salt are not limited in this grade. Butter that has a flavor classification of B or C and total defects in body, color, and salt of two (2) or more shall be U.S. Cooking Grade.

No Grade: Butter that possesses any of the following flavors or contains any of the substances listed under "conditions" or is below the requirements of the U.S. Cooking Grade shall be classified as "No Grade."

Flavors:
- Pronouncedly fishy
- Surface taint
- Limburger
- Tallowy
- Rancid
- Paint or varnish
- Gasoline or kerosene, or fly spray
- Chemical

Conditions:
- Mold
- Grains of sand
- Splinters of wood
- Specks of rust
- Other foreign materials

TENTATIVE U.S. STANDARDS FOR GRADES OF AMERICAN CHEDDAR CHEESE[1]

Production and Marketing Administration, U.S. Department of Agriculture, December 6, 1945

U.S. Grade AA or U.S. Fancy
U.S. Grade A or U.S. No. 1
U.S. Grade B or U.S. No. 2
U.S. Grade C or U.S. Undergrade
No Grade

BASIS OF DETERMINATION FOR U.S. GRADE

The grade of cheese shall be determined on the basis of its characteristics with respect to flavor, body and texture, color, finish, and appearance as set forth below for each grade.

U.S. GRADE AA OR U.S. FANCY

GENERAL SPECIFICATIONS FOR CHEESE OF ALL AGES

Flavor. It shall be free from undesirable flavors.

Body and Texture. The plug should have the appearance of being solid, compact, and close boring. It may have a few small mechanical openings but no large openings. It shall be free from sweet holes, yeast holes, or gas holes of any kind.

Color. May be uncolored or medium-colored but must be uniform and translucent.

Finish and Appearance. Shall be free from cracks in the rind, soft spots, rind rot, scaly paraffin, and other surface defects which may cause deterioration of the cheese. The bandage shall be evenly placed on both ends of the cheese and free from unnecessary overlapping wrinkles. The cheese must not be lopsided and must be free from any huffing and high edges. The starch circles may be left on at time of paraffining or at that time may be removed. The cheese must have a good coating of paraffin or wax that adheres firmly to the surface of the cheese. The cheese shall be of uniform weight.

U.S. GRADE A OR U.S. NO. 1

GENERAL SPECIFICATIONS FOR CHEESE OF ALL AGES

Flavor. It shall be free from undesirable flavors. It may have slight regional or seasonable feed flavors.

Body and Texture. The plug when drawn should have the appearance of being solid and compact, close or medium close. It may have a few mechanical openings but these should not be large and connecting. It may have an occasional sweet or Swiss hole, but not more than two on a plug pulled by a regular size cheese trier. It shall be free from other gas or yeast holes.

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[1] These standards are a reissue of tentative standards originally issued by the Food Distribution Administration, which were approved April 24, 1943, by C. W. Kitchen, Deputy Director, Food Distribution Administration, and became effective May 1, 1943. No change is made in the text of the standards.

Color. May be uncolored or medium colored but must be uniform and translucent; may be slightly seamy.

Finish and Appearance. Shall be free from cracks in the rind, soft spots, rind rot, scaly paraffin, and other surface defects that may cause deterioration of the cheese. The bandage shall be fairly evenly placed on both ends of the cheese and practically free from unnecessary overlapping and wrinkles. The cheese must not be more than slightly lopsided, practically free from high edges, and free from any huffing. The starch circles may be left on at time of paraffining or at that time may be removed. The cheese must have a good coating of paraffin or wax that adheres to the surface of the cheese. The cheese shall be of uniform weight.

U.S. GRADE B OR U.S. NO. 2
GENERAL SPECIFICATIONS FOR CHEESE OF ALL AGES

Flavor. It shall be free from strong, undesirable flavors.

Body and Texture. May be loose and open. May have numerous sweet holes, or scattered gas holes, or yeast holes.

Color. May be uncolored, medium, or high colored. May be seamy, slightly acid cut, or faded, slightly wavy, or slightly mottled.

Finish and Appearance. May have a rough or unattractive appearance. May have scaly paraffin. May be slightly huffed. It may be lopsided but not to the extent the lid will not fit squarely on the box. The rind must be solid and free from soft spots, rind rot, and cracks or openings of any kind. The bandage can be uneven, overlapped, or wrinkled, but must not be burst or torn. There must be no indication that mold has entered the cheese. The starch circles may be left on at time of paraffining or at that time may be removed.

U.S. GRADE C OR U.S. UNDERGRADE
GENERAL SPECIFICATIONS FOR CHEESE OF ALL AGES

Flavor. There shall be no offensive flavors.

Body and Texture. May be loose and open. May have sweet holes, yeast holes, or gas holes.

Color. May be uncolored, medium, or high colored. May be acid cut or faced, wavy, seamy, or mottled. It shall not be wavy or mottled to the extent that it is unpalatable or repulsive.

Finish and Appearance. May have a rough, unattractive appearance. May have scaly paraffin, may be huffed or lopsided, may have a soiled surface but shall be reasonably free from surface mold. The rind must be practically free from rind rot, cracks, or openings. There must be no indication of mold entering the cheese.

"NO GRADE" CHEESE

Cheese of any age having the following defects, or which is below the requirements of U.S. Grade C or undergrade, shall be classified as "no grade" cheese:

Flavor. Any offensive flavor such as putrid, kerosene, gasoline, fly spray, oil or paint, or such flavors as rancid, fishy, chemical, sour, fermented, fruity, onion, or obnoxious weed flavor, or other undesirable flavors to the extent that they are offensive.

Body and Texture. Weak, to the extent a normal plug cannot be drawn from the cheese.

Color. Discoloration caused by foreign material or by bacterial action, or if the color is such that the cheese is unpalatable.

Finish and Appearance. Excessive cracks or openings in rind. Any indication of mold growth in the interior of the cheese. Soft wet rind or rind rot. Cheese mites if there are any openings in the rind.

Cheese marked "no grade" may or may not be edible.

SPECIFIC GRADING REQUIREMENTS FOR DRY WHOLE MILK

Item	Quantity	Gas-packed, premium	Spray-process, extra	Bulk, spray process		Bulk, roller process	
				Extra	Standard	Extra	Standard
Milk	Not less than	26.00%	26.00%	26.00%	26.00%	26.00%	26.00%
Moisture	Not more than	2.25%	2.50%	2.50%	3.50%	3.00%	5.00%
Titratable acidity[2]	" " "	0.15%	0.15%	0.15%	0.17%	0.15%	0.17%
Bacterial estimate	" " "	50,000 per gm.	50,000 per gm.	50,000 per gm.	125,000 per gm.	50,000 per gm.	125,000 per gm.
Solubility index[2]	" " "	0.50 ml.	1.50 ml.	0.50 ml.	1.0 ml.	15.0 ml.	15.0 ml.
Sediment[2]	" " "	No. 2	No. 3	No. 3	No. 4	No. 3	No. 4
Flavor-odor	" " "	Normal[2]	Normal[2]	Normal	Normal	Normal[2]	Normal[2]
Color	" " "	Normal	Normal	Normal	Normal	Normal	Normal
Copper	" " "	1.5 p.p.m.	1.5 p.p.m.	1.5 p.p.m.	3.0 p.p.m.	1.5 p.p.m.	3.0 p.p.m.
Iron	" " "	10.0 p.p.m.	10.0 p.p.m.	10.0 p.p.m.	15.0 p.p.m.		
Oxygen	" " "	2.0%[1]	3.0%[1]				

[1] Calculated to atmospheric pressure. This determination is to be made 7 to 10 days after final gas packaging.

[2] Determination made upon reliquefied sample.

UNFIT FOR HUMAN CONSUMPTION

Any dry whole milk failing to meet requirements for Standard Grade may be considered an ungraded product, provided that any dry whole milk having a flavor or odor or other characteristics indicative of decomposition or neutralization, or which fails to meet the General Requirements for dry whole milk, shall be termed "Unfit for Human Consumption."

SPECIFIC GRADING REQUIREMENTS FOR NON-FAT DRY-MILK SOLIDS

EXTRA GRADE

Extra Grade is so designated to indicate the highest quality of non-fat dry-milk solids, and in addition to the foregoing General Requirements, shall meet the following specifications:

Item	Spray not greater than	Vacuum drum not greater than	Atmospheric roller not greater than
Milk	1.25%	1.25%	1.25%
Moisture	4.00%	4.00%	4.00%
Titratable acidity	0.15%	0.15%	0.15%
Solubility index[1]	1.25 ml.	2.00 ml.	15.00 ml.
Bacterial estimate	100,000 per gm.	100,000 per gm.	100,000 per gm.
Sediment[1]	No. 3	No. 3	No. 3

[1] Determination made upon reliquefied sample.

Extra Grade non-fat dry-milk solids shall be entirely free from hard lumps. The dry sample as well as the reliquefied sample shall be entirely free from any storage or scorched flavor or odor.

STANDARD GRADE

Standard Grade includes all non-fat dry-milk solids that fail in one or more particulars to meet the requirements of Extra Grade, but it shall meet or come within the following specifications:

Item	Spray not greater than	Vacuum drum not greater than	Atmospheric roller not greater than
Milk	1.50%	1.50%	1.50%
Moisture	5.00%	5.00%	5.00%
Titratable acidity[1]	0.17%	0.17%	0.17%
Solubility index[1]	2.00 ml.	5.00 ml.	15.00 ml.
Bacterial estimate	300,000 per gm.	300,000 per gm.	300,000 per gm.
Sediment	No. 4	No. 4	No. 4

[1] Determination made upon reliquefied sample.

Standard Grade non-fat dry-milk solids shall be reasonably free from hard lumps but may have a slight storage or slightly scorched flavor or odor before and after reliquefication.

Unfit for Human Consumption

Any non-fat dry-milk solids failing to meet requirements for **Standard** Grade may be considered an ungraded product, provided that any non-fat dry-milk solids having a flavor or odor or other characteristics indicative of decomposition or neutralization, or which fail to meet the General Requirements for non-fat dry-milk solids, shall be termed "Unfit for Human Consumption."

Tentative specifications have been prepared for such products as buttermilk and whey but are not included here.

INDEX

A

Abortion (*see* Brucellosis)
Acetic acid production, 126
Acetone from whey, 346
Acid, effect of, on milk, 22
Acidity, of cream for butter making, 239
  of milk, 22, 68, 76
  test for, 390
    in cream grading, 234
  titration of, 68, 390
Acidophilus milk, 351
Acids, amino (*see* Amino acids)
  effect of, on milk, 80
  formulae of, 422
  molecular weights of, 422
  tenth-normal solutions, 422
  volatile, in milk, 126
Actinomycosis, 206
Adenine, 48
Adulteration of milk, 73, 220, 386, 400
Aerobacter aerogenes, 126
Albumin, 36, 40, 56, 68, 76, 80
  in butter, 40
  coagulation of, 40, 76
  in colostrum, 56
  commercial uses of, 40
  composition of, 40
  influence on, of acids, 40, 76
    of heat, 40, 76
    of rennet, 40
  properties of, 40
  (*See also* Lactalbumin)
Alcaligenes viscosus, 127
Alcohol test, 404
Alcoholic fermentation, 129
Alfa churn, 256
Alkali-producing bacteria, 127
Alpha-tocopherol, 48, 91
Amino acids, essential, 85, 93
Amylase, test for, 406
Annato, 241
Antiseptics, action of, on microorganisms, 110
Arachidic acid, 29, 30
Aralac casein fiber, 39
Arginine, 85, 93
Arithmetic, dairy (*see* Dairy arithmetic)
Arnold test, 406
Ascorbic acid, 48, 90, 202
Ash, in colostrum, 56
  composition of, 44
  influence of feed on, 65
  of milk, 23, 44, 50–54, 56, 68, 69, 73, 76
  relation of, to freezing point, 73
  requirements of, 86
  in skeleton, 86
  source of, 86
  specific gravity of, 69
  uses of, 45
Aspergillus repens, 341
Ayrshire milk, 26, 33, 53, 54, 62, 72, 201

B

Babcock test, 8, 132–150, 376
  apparatus for, 135, 146, 383, 411
    centrifuges, 138, 148, 412
    glassware, calibration of, 383
      description of, 146, 411
      specifications for, 377, 411
  for buttermilk, 376
  for cream, 141, 146
  defects in, 139
  for fat, 411
  historical, 8, 133, 243
  for homogenized milk, 383

Babcock test, for milk, 135
  modified, 376
    for buttermilk, 376
    for cheese, 378
    for chocolate milk, 382
    for condensed milk, 382
    for homogenized milk, 383
    for ice cream, 379
    for skim milk, 376
    for whey, 376
  principles underlying, 134
  procedure for, 133, 135, 141
  for skim milk, 376
  water bath for, 139, 145, 412
  for whey, 376
Babylonia, cow worship in, 1
Bacillus coagulans, 128
Bacillus subtilis, 127, 128
Bacteria, in capsules, 104
  cell structure of, 103
  colonies of, 116, 117
  definition of, 102
  distribution of, 102
  effect on, of acid, 109
    of pasteurization, 114, 187
  flagella, 104
  motility of, 104
  numbers of, in milk, 103, 116
  photomicrograph of, 103, 104
  reproduction of, 104
  size of, 102
  sources of, in milk, 118
  spore of, 104
  (*See also* Microörganisms)
Bacterial counts, 103, 117, 409
  effect on, of clarification, 185
    of homogenization, 312
    of separation, 179
  official methods for, 409
Bacteriology in dairying, 102
Bacterium lactis, 124
Bacterium lactis acidi, 124
Bang's disease (*see* Brucellosis)
Barns, dairy, 204, 207
Base exchange, effect of, on curd tension, 201
Bases, formulae for, 422
  molecular weights of, 422
Bases, tenth-normal solutions of, 422
Beef fat, composition of, 28
Beets, effect of, on milk fat, 35
Benzoic acid, 110
Bichloride of mercury, 110
Bichromate of potash (*see* Potassium bichromate)
Bisque, 293
Bitch's milk, 51
Bitter milk, 56, 58, 80, 128
Bixa orellana (*see* Annato)
Borax, 110
Borden, Gail, patent by, 15
Boric acid, 110
Botulism, toxin in, 116
Bread, non-fat dry-milk solids in, 93
Breed, influence of, on color of milk, 46, 54
    on composition of milk, 33, 34, 52
    on quality of dairy products, 55
    on size of fat globules, 26, 33
Breed method for microscopic bacteria count, 410
Breeds, dairy, 53
Brine, effect of, on microörganisms, 112
Brown Swiss milk, 201
Brownian movement, 104
Brucellosis, 119, 129, 206, 223
Buckwheat middlings, effect of, on milk fat, 35
Buffalo, water, milk from, 21, 51
Bulgarian buttermilk, 350
Butter, 25, 225–265
  adulterated, 58
  albumin in, 40
  analysis of, for fat, 398
    Kohman, 396
    for moisture, 398
    for salt, 399
  arachidic acid in, 30
  aroma bacteria in, 126
  ash content of, 45
  body defects in, 262
  buttermilk per pound of, 344
  butyric acid in, 30

Butter, **butyrin** in, 30
  by-products of, 16
  calculation of, color for, 254, 364
    overrun, 363
    salt, 255, 364
    yield, 363
  calories in, 98
  capric acid in, 30
  caproic acid in, 30
  caprylic acid in, 30
  carotene in, 240
  churning of, 241
  color of, 72, 240, 259, 364
    artificial, 240
    defects in, 262
    market requirement for, 240
  composition of, 25, 229, 254, 363
  consumption of, 18, 19, 423
  cooked taste in, 237
  cream for, 230
    ripened, 239
  creamery, 14, 258, 423
  curd in, 229, 400
  dairy, 259
  defects in, 237, 261
  dry, 25
  factory for, first, 4
  farm-made, 13, 228, 239, 259, 262
  fat content of, 25
  federal regulations for, 25, 229, 254
  firmness in, effect of breed on, 34
  fishy flavor in, 46, 261
  flavor of, 42, 230, 260
  food value of, 98
  grading of, 259
  granules in, 245, 249
  greasy, 256, 262
  hardness of, 31
  historical statements concerning, 3, 132, 151, 225
  household foam test of, 407
  lactose in, 43
  lauric acid in, 30
  leaky, 262
  lecithin in, 46
  linoleic acid in, 30
  manufacture of, 225–265
Butter, manufacture of, by-products from, statistics on, 16
    processes involved in, 229
    (*See also* Butter making)
  market grades of, 259, 423
  marketing of, 259
  melting point of, 31
  milk used for, 11
  moisture in, scale for, 399
    test for, 398
  mold in, detection of, 400
    hyphae and mycelia of, 400
    Wildman test for, 400
  molds in, 106, 109, 262
  mottles in, 256, 261
  myristic acid in, 30
  nature of, 25
  neutralization of cream for, 234
  off-flavors in, 261
  oil and fat in, 25, 200
  oleic acid in, 30
  overrun of, 254, 363
  packing stock, 259
  palmitic acid in, 30
  pasteurization of cream for, 235
  pink or red spots on, 116
  printing and wrapping of, 257
  process, 259
  production of, in factories, 13
    leading states in, 13
  rancidity of, 30, 31, 47, 115, 253, 261
  renovated, 259
  retail delivery of, 214
  from ripened cream, 258
  salt in, 229, 254, 259, 261, 264
  sampling of, 397
  score card for, 261
  scoring of, 261
  sediment test for, 396
  separation of milk for, 226, 229
  specific heat of, 74
  standards for, 229, 254, 260, 423
  starters for, 237
  statistics on, 13, 228, 423
  stearic acid in, 30
  storage of, 258
  from sweet cream, 230, 234, 258

Butter, taste of, characteristic, 30
  tests for, 396
  texture of, 31
  unsalted, 259
  vitamins in, 98
  whey, 259
  working of, 255
Butter making, by-products from, 16
  cream for, 230, 239
  factory system of, 4, 228
  farm, 225, 228, 259, 262
  history of, 4, 225
  neutralized cream for, 229, 234
  overrun in, 254
  process of, 229
  ripened cream for, 239
  salting in, 254
  starters in, 237
  working in, 255
  (*See also* Butter; Churn; Churning)
Butter printer, 264
Butter trier, 398
Buttermilk, 241, 252, 344
  acidity of, 100, 344
  amount of, available, 16
  ash content of, 45
  Babcock test for, 376
  Bulgarian, 350
  color of, 241
  commercial uses of, 16, 344
  composition of, 344
  condensed, 315, 323, 345
  cultured, 350
  dried, 16, 331, 333, 336, 344
  fat content of, 344
    losses in, 247, 252
  food value of, 100, 344
  lecithin in, 46
  per pound of butter, 344
  resulting from churning, 344
  retail delivery of, 214
  semisolid, 315
  sour, composition of, 344
  testing of, 376
  total solids in, 419, 422
  utilization of, 16, 323, 344
  viscosity of, 79
Butyl alcohol from whey, 346
Butyric acid, 28, 128
Butyrin, 30–32
By-products, from butter making, 16, 344
  from cheese making, 16, 345
  from milk, 341

C

Calcium, in cheese, 99
  in milk, 44, 76, 86, 89
Calcium carbonate as neutralizer, 234
Calcium caseinate, 37, 272
  influence of, on color of milk, 71
Calcium hydroxide, formula for, 422
  molecular weight of, 422
  as neutralizer, 234
  tenth-normal solution of, 422
Calcium oxide, formula for, 422
  molecular weight of, 422
  as neutralizer, 234
  tenth-normal solution of, 422
Calcium pantothenate added to milk, 202
Calcium paracaseinate, 38, 272
Calcium phosphate, physical state of, in milk, 68
  precipitation of salts of, 76
Calories, definition of, 74, 83
  in various foods, 83, 94, 96, 98
Camel's milk, 21, 51
Capric acid, 28, 36, 285
Caprin, 30
Caproic acid, 28, 36, 285
Caprylic acid, 28, 36, 285
Carbohydrates in milk, 84
Carbon dioxide in milk, 48, 69
Carotene, addition of, to milk, 202
  in body fat, 46
  in butter, 240
  influence of feed on, 47, 72, 240
  in milk, 46, 47, 71
  relation of breed to, 46, 72, 240
  source of, 46, 71, 240
Carotenoids in milk, 46
Casein, in cheese, 37

- Casein, coagulants for, 272
  - coagulation of, 37, 75, 272, 317, 348
  - in colostrum, 56
  - commercial uses of, 38, 348
  - composition of, 348
  - decomposition of, by bacteria, 127
  - dry, 348
  - effect on, of acid, 37, 80, 348
    - of alcohol, 37
    - of heat, 37, 75, 348
    - of rennet, 37, 272, 348
  - glue from, 39, 80, 348
  - in ice cream, 37
  - influence of, on viscosity of milk, 78
  - manufacture of, 38, 348
  - in milk, 37
  - paints from, 39, 348
  - physical state of, in milk, 37, 68
  - plastics from, 38, 348
  - precipitation of, in milk, 126
  - preparation of, 38
  - properties of, 37
  - relation of, to adhesiveness of milk, 80
  - from skim milk, 348
    - yield of, 348
  - specific gravity of, 69
  - sulfur in, 44
- Casein fiber, 348
- Catalase in milk, 47, 48
- Cat's milk, 51
- Centrifuge for Babcock test, 138, 148, 412
  - speed requirements for, 149
- Certified milk, 211, 224
- "Cheerio," 294
- Cheese, 266–289
  - American Cheddar (*see* Cheddar below)
  - ash in, 45, 87
  - Babcock test for, 378
  - Backstein, 286
  - Blue, manufacture of, 284
  - Brick, 36, 268, 271, 285
  - calcium in, 99
  - Camembert, 36, 268, 287
- Cheese, casein in, 36
  - Cheddar, 266, 268, 270, 271, 273
    - bacteria in, 271, 279
    - color of, 276, 282
    - composition of, 25, 271
    - curing of, 271, 278
    - defects in, 279, 281
    - equipment for, 273
      - curd knives, 273
      - curd mill, 274
      - curd rake, 274
    - flavor of, effect of fat on, 25
    - forms of, 279
    - manufacture of, 271, 275
    - market grades and terms for, 280
    - milk for, 13, 275
    - origin of, 273
    - paraffining of, 278
    - pasteurization of milk for, 270, 275
    - from pasteurized milk, 270, 275
    - riboflavin in, 89
    - ripening of, 275
    - score card for, 281
    - from skim milk, 280
    - starter for, 275
    - from whole milk, 280
    - yield of, 345
  - classification of, 268
  - Club, 289
  - Colby, 268
  - color for, 276
  - composition of, 271
  - consumption of, 18, 19, 423
  - Cottage, 214, 268, 270, 280, 288, 335
  - Cream, 200, 270, 280, 288
  - curing of, enzymes in, 271, 279
    - microörganisms in, 271, 279
  - domestic Swiss, protein content of, 36
  - Edam, 266, 269
  - Emmental, 266, 269, 283
    - (*See also* Swiss, below)
  - enzymes related to ripening of, 47, 272
  - European, 266

Cheese, factory for, 4, 14, 132, 225, 267
  fat in, 25
  food value of, 99
  foods from, 280, 289
  Gammelost, 266
  Gorgonzola, 266, 268
  Gouda, 266
  grades of, 425
  hard, 269, 273
  history of, 1, 3, 4, 14, 132, 266
  home-made, 3
  iron in, 99
  Lactobacillus casei in, 279
  lactose in, 43
  Liederkranz, 268
  Limburger, 266, 268, 269, 286
  Loaf, 268, 280, 289
  marketing of, 280, 425
  milk used for, 13, 271
  moldy, 106, 109
  Mysost, 346
  nature of, 268
  Neufchatel, 268, 271, 289
  New York (*see* Cheddar, above)
  paraffining of, 275, 278
  Parmesan, 266
  Philadelphia Cream, 270, 288
  phosphorus in, 99
  pink spots on, 116
  press, 274
  Primost, 14, 40, 266, 346
  process, 14, 268, 280, 289
  production of, in United States, 14
  protein in, 36
  proteolysis in, 127
  reworked, 289
  Ricotta, 346
  ripening of, 115
    milk for, 275
  Roquefort, 52, 266, 268, 270, 271, 284, 289
    American-type, 284
    composition of, 271
    fat-splitting molds in, 115
    protein in, 36
  sediment test for, 396
  semihard, 269
Cheese, soft, 36–37, 268, 270, 286
  standards for, 425
  statistics on, 14, 423
  Stilton, 266
  Streptococcus lactis in, 279
  sulfur in, 99
  Swiss, 36, 266, 268, 270, 271, 283
  testing of, 378
  types of, on market, 14, 268
  use of, by Vikings, 1
  varieties of, 14, 269
  whey, 16, 276, 345
  Wisconsin (*see* Cheddar, above)
  yield of, 270, 345
  Ziger, 346
Cheese bandages, 274
Cheese circles, 274
Cheese hoops, 274, 279, 280
Cheese industry, 267
Cheese spreads, 289
Cheese making, by-products of, 16
  curd formation in, 272
  factory system of, 4, 266
  fat losses in, 28
  milk for, 13, 14, 55, 271
  rennet for, 272, 276
  (*See also* Cheese)
Chemistry in dairying, 8
Chlorine solutions, 110, 209, 210
Chocolate-milk testing, 382
Cholesterol in milk, 46
Churn, Alfa, 256
  construction of, 227, 243
  continuous, 256
  Fritz, 256
  history of, 242
  metal, 242
  roller-type, 227, 243
  rollerless-type, 242–244
  treatment of, 245
  with upright dasher, 228
  (*See also* Churning)
Churning, difficulty in, 27, 249, 251, 253
  factors influencing, 247
    acidity of cream, 250
    composition of butterfat, 31, 249

Churning, factors, influencing, fullness of churn, 251
    richness of cream, 251
    size of fat globules, 27, 250
    speed of churn, 252
    temperature of cream, 247
    viscosity of cream, 251
  fat losses in, 252
  nature of, 241
  overrun in, 254
  procedure for, 245
  temperature in, influence of fatty acids on, 31, 247
  theories concerning, 241
Citrates in milk, 69, 76
Citric acid, fermentation of, 126
Clarification of milk, 183–187
  effect of, on bacterial count, 180, 185
    on cream line, 187
    on keeping quality, 186
Clarifier, 183
  airtight, 184
  efficiency of, 184
  sectional view of, 186
Clostridium butyricum, 127, 128
Colloidal phosphate in milk, 71
Color of milk, influence on, of breed, 21, 46, 47, 54
  of calcium caseinate, 71
  of carotene, 46, 47, 71, 72
  of colloidal phosphate, 71
  of fat, 22, 66, 71
    of feed, 22, 47, 66, 72
    of heat, 22
    of lactochrome, 47, 72
    of milk solids, 22
    of riboflavin, 72
Colostrum, composition and properties of, 56, 69
Composite sample, 142, 371
Composition of milk (*see* Milk and specific milk products)
Concentrated milk, 313–341
  food value of, 100
  history of, 15
  statistics on, 15, 18, 19, 423
Condensed buttermilk, 315, 323
Condensed milk, 313–325
  Babcock test for, modified, 382
  classification of, 315
  color of, 41
  composition of, 315, 324
  consumption of, 19, 423
  containers for, 323
  cooling of, 321
  defects in, 322, 340
  equipment for, 318
  federal standards for, 316
  food value of, 100
  history of, 15, 313
  manufacture of, 317
  marketing of, 323
  microörganisms in, 108, 111, 339
  milk used for, 14, 55
  plain, 315
  plant for, 313, 318, 326
  production of, 15
  properties of, 316
  standardization of, 321
  statistics on, 423
  superheated, 315, 317, 339
  sweetened, 315, 322
    buttons in, 323, 341
    composition of, 315, 339
    containers for, 324
    federal standards for, 316
    lactose crystallization in, 322, 323
    microörganisms in, 340
    processing of, 315, 322
    testing of, 382
  uses for, 295, 322
  vacuum pans for, construction and operation of, 301–304
Condensed skim milk, 324, 343
Condensed whey, 315, 346
Condensing milk, 318
Contagious abortion (*see* Brucellosis)
Conversion tables, 420
Cooling milk, 210
Cooperatives, 215
Copper in milk, 44
Corn oil, effect of, on milk fat, 35
Corn-oil silage, effect of, on milk fat, 30, 35

Corn-oil sugar in ice cream, 296
Corn-oil syrup in ice cream, 296
Corrosive sublimate, 110, 370, 375
Cottonseed meal, effect of, on fat, 30, 34, 35
Cow, body of, as source of bacteria, 119
  health of, 206, 211, 223
  historical record concerning, 1
  milk of, composition of, 51
  milk and fat production of, 9, 10, 174
  worship of, by ancients, 1
    goddess Hathor as, 1
Cream, acidity of, 233, 239, 250, 391
  albumin in, 40
  alcoholic fermentation in, 129
  Babcock fat test for, 141
  bacteria for ripening, 127, 237
  balance for Babcock test, 142,147
  bitter flavor in, 128
  for butter making, 230
  care of, on farm, 231
  churnability of, factors affecting, 247
  churned, sampling of, 370
  churning of, 24, 27, 34, 241
  composite sample of, 375
  cooling of, 195, 235
  definition of, 151
  dry, 331
  fat content of, 24, 141, 151
  feed flavors in, 231
  freezing of, 73
  frozen, 369
  grades of, 233
  homogenization of, 198
  lactose in, 43
  lecithin in, 46
  methylene-blue test of, 404
  mold detection in, 400
  neutralization of, 234, 364
  off-flavors in, 230
  pasteurization of, 235
  plastic, 24
  price of, per gallon, calculation of, 355
  reconstituted, 200
Cream, regulations on, 24
  ripening of, 235, 239
  ropiness in, 127
  sampling of, 368
  sediment test for, 233
  separation of, 151–179
    (*See also* Separation)
  separator for (*see* Separator)
  shipping of, effect of, 27
  sour, churning of, 250
    sampling of, 370
  specific gravity of, 355, 416
  specific heat of, 74, 75
  standardization of, 359
  sweet, churning of, 250
  types of, 24, 230
  use of, in ice cream, 294
  viscosity of, 78, 199, 241
  weight per gallon of, 355, 416
  whipping, 24, 79, 151
Cream line, 187
  effect on, of clarification, 187
    of freezing, 73
    of heat, 73
    of homogenization, 198
Cream plug, 370
Cream powder, 331
Creamer, deep-setting, 154
Creamery, modern, 226
Creamery system, history of, 132, 225
Creatine, 48
Creatinine, 48
Crowe test for ice cream, 380
Cryoscope, 401
Curd, determination of, in butter, 400
Curd tension, 97, 201

D

Dairy arithmetic calculations, on butter, coloring, 364
    overrun, 363
    salt, 364
    yield, 363
  on cream, amount separated, 356
    neutralization, 364

- Dairy arithmetic calculations, on cream, standardization, 359
    - value per gallon, 355
  - on fat, average percentage, 353
    - price, 356
  - on ice cream, composition, 366
    - overrun, 367
  - on markets, most profitable, 356
  - on milk, fat in, 352
    - neutralization, 364
    - price of, 354
    - standardization, 359
  - on skim milk, value of, 357
- Dairy barn, 203, 207
- Dairy cooperatives, 215
- Dairy cows, number of, 9
- Dairy equipment for sterilization, 121
- Dairy-farm inspection, score card for, 221, 413
- Dairy hygiene, 118
- Dairy industry, development of, 3, 11
  - extent of, 10
- Dairy processes, 151–202
- Dairy products, consumption of, 18, 423
  - demand for, 17
  - in diet, 10, 98
  - disease transmission through, 129
  - early uses of, 1
  - effect of light on, 111
  - exports of, 20
  - fat content of, 24
  - influence of breed on, 55
  - Pennsylvania test for, 379
  - rancid flavor in, 31
  - specific heat of, 74
  - Swope test for, 379
- Dairy research and technology, 7, 299
- Dairy scene about 3500 B.C., 2
- Dairying, history of, 1–10
- Danish heater, 193
- Density of milk (*see* Specific gravity)
- Diacetyl, 126, 239
- Diastase, 48
- Dicalcium phosphate, effect of heat on, 77
- Diphtheria, 116, 122, 129, 130
- Diseases transmitted through milk and milk products, 116, 119, 120, 122, 129, 188
- Disinfectants, 110
- Dried milk (*see* Dry milk)
- Drugs, effect of, on composition of milk, 66
- "Drumstick," 294
- Dry butter, 25
- Dry buttermilk, 16, 331, 345
- Dry cream, 331
- Dry ice-cream mix, 15, 332, 337
- Dry milk, 325–341
  - action of rennet on, 335
  - classification of, 338
  - color of, 41, 334, 337
  - composition of, 332, 337
  - containers for, 337
  - defects in, 336
  - equipment for, 325
  - fat in, 25
  - food value of, 98
  - gas packing of, 327, 338
  - grading of, 330, 338, 428
  - history of, 1, 15, 325
  - hygroscopic properties of, 334
  - lactose in, 44
  - manufacture of, 325
  - microbiology of, 339
  - packaging of, 327
  - processes for, atmospheric-drum, 329
    - dough, 325
    - drum, 328, 338
    - spray, 326
    - vacuum-drum, 328, 330
  - production of, 15
  - properties of, 333
  - reconstituted, 338
  - solubility of, 333
  - standardizing of, 330
  - standards for, 428
  - taste in, 334
  - types of, 331
  - uses of, 1, 295, 335, 423

Dry-milk solids, non-fat, 331
  (*See also* Dry skim milk)
Dry skim milk, 15, 18, 19, 331, 333, 336, 343, 423, 429
Dry whey, 16, 332
Dry whole milk, 1, 423, 428
Dust, microörganisms from, 121

E

Eggs in ice cream, 308
Egypt, cow worship in, 1
Electrical pasteurization, 111, 196
Emmental cheese (*see* Cheese, Swiss)
Emulsification of milk, 200
Enzymes, action of, 115
  in cream, 231, 253
  effect of, on milk, 80
  fat-splitting, 47
  of microörganisms, 114
  in milk, 47, 80, 115, 406
  nature of, 114
  relation of, to cheese ripening, 47, 272, 279, 285
    to off-flavors, in cream, 232, 253
      in milk, 47, 80, 114
  rennet-like, 128
  tryptic, 201
  types of, 47, 115
  in udder, 129
  (*See also* Catalase; Diastase; Galactase; Lactase; Lipase; Peroxidase; Reductase)
Escherichia coli, 126
"Eskimo Pie," 294
Evaporated milk, 314–317, 341
  composition of, 25, 316
  containers for, 323
  defects in, 341
  fishy flavor in, 46, 341
  history of, 313
  homogenization of, 199, 322
  for infant feeding, 201
  keeping quality of, 322, 341
  manufacture of, 317
  microörganisms in, 341
  milk used for, 14
  per capita consumption of, 18, 423
  production of, 15
  sterilization of, 114, 322, 340
  testing of, 382
  (*See also* Condensed milk)
Evaporator, 314

F

Factory system of dairy manufacturing, 4
Fat, beef, 28
  calories in, 83
  carotene in, 240
  (*See also* Milk fat)
Fat globules, 22, 25, 197
  factors affecting, 27, 57, 73, 78, 197
  fat-like substances on, 25
  lecithin on, 26
  membrane of, 26
  in milk, 22, 25, 56, 152
  proteins on, 26
  rising of, in milk, 152
  size of, 26, 198
    factors affecting, 26, 33, 56
    importance of, 27, 28, 152
  surface characteristics of, 26
Fats, decomposition of, by microorganisms, 115
Fatty acids, boiling point of, 32
  composition of, 29
  glycerides of, 28
  influence of, on character of milk fat, 32
    on churning, 31
    on color of milk, 22, 71
    on flavor of butter, 30
  influence on, of breed, 33
    of feed, 34
    of lactation period, 34
    of plane of nutrition, 33, 35
  insoluble, 29
  melting point of, 31, 32, 35
  in milk fat, 28
  non-volatile, 29
  properties of, 31
  relation of, to melting point of fat, 31

Fatty acids, relation of, to rancidity, 30
  soluble, 29
  specific gravity of, 32
  volatile, 29
Feed influence, on off-flavors in milk and cream, 66, 70, 128, 231–233
  relation of, to composition of milk fat, 34, 65, 172, 249
Fermentation test for milk, 405
Fermented milk, 100, 126, 314, 349
  (*See also* Milk, fermented)
Fibrin in milk, 41
Fiili, 350
Filters for milk, 182, 183
Filtration of milk, 181, 182
Fishy flavor, 46
Flavor of milk, 22, 58, 66, 70, 71, 126
  effect of heat on, 77
Food, 87
  calories supplied by, 98
  dairy products for, 98
  digestibility of, 92
  economy of, 92
  energy equivalents of, 94
  fat in, 83
  palatability of, 91
  requirements of, 91
Foods, carbohydrates in, 83
  energy in, 83, 94
  minerals in, 86
  proteins in, 84, 94
  vitamins in, 87
  water content of, 83
Foremilk, bacterial content of, 118
Formalin, 110, 370, 375
Freezer, ice-cream, 303, 304
Freezing point of milk, 70
  determination of, 73, 400
Fritz churn, 256

G

Galactase in milk, 47
Garget, 119, 127, 206
Garrett-Overman test for ice cream, 380
Gases in milk, 48
Gelatin, 122, 296, 308, 310, 311
Genghis Khan, 1
"Germicidal" period in milk, 123
Germicides, 110
Gioddu, 350
Globulin, in colostrum, 56
  in milk, 41, 68
Glycerides, 28
Glycerol, 28
Goat's milk, composition of, 51
  food value of, 52
  Malta fever from, 130
  production of, 21
Grain, bacteria from, 126
Grass, effect of, on milk fat, 31, 35
Gravity creaming (*see* Separation)
Guaiac test for heated milk, 406
Guanine, 48
Gurnsey milk, characteristics of, 26, 33, 53–55, 60, 72, 201

H

Hathor, cow goddess, 1
Heated milk, test for, 406
Hill test, 201
Histidine, 85, 93
History of dairying, 1–10
Holstein milk, characteristics of, 24, 26, 33, 53–55, 59, 60, 62, 72, 201
Homogenization, 196–200
  effect of, on curd tension, 97, 199
    on fat globules, 198
  of ice-cream mix, 199, 302
Homogenized milk, testing of, 224 383
Homogenizer, action of, 198
  history of, 196
  for ice-cream mix, 199, 302
  types of, 196
  use of, 199
Honey in ice cream, 296
Hortvet cryoscope, 401
Household foam test for oleomargerine, 407
Human milk, 51
Hydrochloric acid, molecular weight of, 422
  tenth-normal solution of, 422

Hydrogen-ion concentration of milk, 22, 68, 394
Hydrogen peroxide, 110
Hygiene in dairy, 118
Hyphae of molds, 106, 400

I

Ice cream, Babcock test for, modified, 379
  brick, 305
  bulk, 305
  calculation, of composition of, 366
    of overrun, 367
  classification of, 292
  commercial, 294, 308
  composition of, 292, 294, 308, 366
  consumption of, 16, 19, 423
  Crowe test for, 380
  defects in, 308
    of body and texture, 309
    of color, 309
  definition of, 290
  distribution of, 309
  eggs in, 308
  factory, 291
  fat in, 25, 294, 308
  flavoring materials for, 294, 297
  food value of, 99
  in forms, individual, 306
  freezing of, 302
  fruit, 294
  Garrett-Overman test for, 380
  gelatin for, 122, 296, 308, 310, 311
  history of, 16, 290
  homemade, 310
  honey in, 296
  ingredients used in, 16, 294, 301
    quality of, 295
  manufacture of, 297
  marketing of, 309
  microbiology of, 311
  milk for, 292, 294, 308
  Minnesota law on, 292
  novelties in, 294
  overrun of, 303, 367
  proteins in, 36
  quality of, 306
Ice cream, sandiness in, 43
  sanitary aspects of, 312
  special, 293
  stabilizers for, 294, 296
  standards for, 292, 293
  statistics on, 16, 423
  sweeteners for, 296, 308
  testing of, 379
  viscosity of, 79
  weight of, per gallon, 367
Ice-cream freezer, 302, 303
Ice-cream laboratory, 298
Ice-cream mix, aging of, 302
  calculation of, 298
  dry, 15, 332
  freezing of, 302
  homogenization of, 199, 302
  pasteurization of, 301
  preparation of, 297
  viscosity of, 79, 302
Ices, 294
Inosital, 90
Intestinal disturbances, 121, 129
Iodine in milk, 44, 65
Iron, in cheese, 99
  in milk, 44, 87
Isoleucine, 85, 93

J

Jersey milk, characteristics of, 24, 26, 33, 53–55, 58, 60, 72, 201
Junket, 80

K

Kaeldermaelk, 350
Kay and Graham test, 406
Kefir, 350
"Koagulation" vitamin, 91
Kohman test, for butter, 396
Koumiss (Kumyss), 52, 349

L

Laboratory, milk-plant, 220
Lactalbumin, 40, 41, 68
  (*See also* Albumin)

Lactase, 48
Lactation, stage of, influence of, 26, 31, 33, 34, 55, 129
Lactic acid, in buttermilk, 100, 344
  calculation of, 390
  effect of, on casein, 272
  fermentation of, 124
  from lactose, 42
  in milk, 22, 69
  molecular weight of, 365, 422
  neutralization of, 364
  tenth-normal solution of, 422
Lactic-acid-forming bacteria, 124
Lactobacilli in Swiss cheese, 283
Lactobacillus acidophilus, 126, 351
Lactobacillus bulgaricus, 126, 350
Lactobacillus casei, 126, 279
  in Cheddar cheese, 279
Lactochrome in milk, 47, 72
Lactoflavin, 47
  (*See also* Lactochrome; Riboflavin)
Lactoglobulin, 36, 41, 44
Lactometer, 70, 388, 418
Lactose, 23, 41, 68
  in butter, 43
  in buttermilk, 43
  in cheese, 43, 271
  in colostrum, 56
  composition of, 41
  fermentation of, 41, 42, 124, 129
  in ice cream, 43
  manufacture of, 346
  in milk, 23, 41, 42, 50, 68
  properties of, 41
  relation of, to freezing point, 73
  in skim milk, 43
  specific gravity of, 69
  in sweetened condensed milk, 43
  sweetness of, 41
Lange-milch, 350
Lange-wei, 350
Lard, 28
Lauric acid, 28
Leben, 350
Lecithin, associated with fat globules, 26
  in dairy products, 45
Lecithin, in milk, 26, 45
  trimethylamine from, 46
Leucine, 93
Leucocytes in colostrum, 56
Linoleic acid, 29, 30
Linseed meal, effect of, on milk, 31, 35
Lipase, in milk, 47, 58, 253
  relation of, to bitter milk, 47, 58, 80, 128
    to rancidity, 47, 58, 80
Livestock improvement, 8
Llama's milk, 21
Lucas and Trout method for testing fat in homogenized milk, 383
Lumpy jaw, 206
Lye solution for milk utensils, 210
Lysine, 85, 93

M

McKay sampler, 374
Magnesium oxide, molecular weight of, 422
  as neutralizer, 234
  tenth-normal solution of, 422
Malt sprouts, effect of, on milk fat, 35
Malta fever, 130
Malted milk, 336
Maltose syrup in ice cream, 296
Manure, bacteria in, 126
Mare's milk, 21, 51, 52
Market milk, 203, 224
  consumption of, 19, 423
  containers for, 219
  delivery of, 211, 214
  development of, 4, 13, 203, 212
  distribution problems of, 218
  grades of, 223
  and health control, 205, 219
  homogenized, 199
  milk used for, 11
  pasteurization of, 216
  plants for, 215
  problem of, complexity of, 204, 218
  production of, 205

Market milk, purchasing methods for, 214
  standardization of, 359
  statistics on, 13, 203, 423
  supervision of, public, 205, 212
  transportation of, 205, 212, 214
  (*See also* Milk)
Marketing, of butter, 257
  of cheese, 280
  of condensed milk, 323
  of dry milk, 337
  of ice cream, 309
Marschall rennet test, 402
Mastitis, 119, 206
Matzoon, 350
Mayflower, lack of cattle on, 1
Measure, standard units of, 417
Medical Milk Commission, 212
Meniscus, 139, 143
Mercuric chloride as preservative, 375
Mercury bichloride (*see* Bichloride of mercury)
Methionine, 85, 93
Methylene-blue reduction test, 403
Microörganisms, 102–131
  in Brick cheese, 286
  in Camembert cheese, 287
  in Cheddar cheese, 271, 275, 279, 282
  in condensed milk, 323, 339
  in Cottage cheese, 288
  counting of, methods for, 117, 409
  in cream and skim milk, 180, 231
  decomposition products from, 107, 115
  in dry milk, 340
  effect on, of clarification, 185
    of electricity, 111
    of filtration, 183
    of pasteurization, 187
    of separation, 179
    of straining, 181
    of temperature, 112
    of thunderstorms, 111
  enzymes from, 114
  in fermented milk, 349
  growth of, factors influencing, 107
Microörganisms, growth of, products of, 114
  in ice cream, 311
  importance of, in dairying, 102
  in Limburger cheese, 287
  in milk for cheese making, 271
  miscellaneous changes due to, 116, 231
  nature of, 102
  nomenclature of, 107
  pigments from, 116
  relation of, to cream ripening, 127, 237
    to fermentation of milk, 124, 129
  in Roquefort cheese, 284
  sources of, in milk, 118
  in starters, 124, 237
  in Swiss cheese, 283
  toxins from, 116
  (*See also* Bacteria; Molds; Yeasts)
Milk, abnormal tastes and odors in, 70, 126, 206
  acidity of, 22, 68, 178, 390
  acidophilus, 251
  adenine in, 48
  adhesiveness of, 79
  adulteration of, 220, 400
    detection of, 386, 400
  for adults, 97
  albumin in, 40, 68
  alcohol test of, 404
  alcohol-soluble proteins in, 41
  alcoholic, 129
  alkali production in, 127
  alpha-tocopherol in, 48, 91
  amino acids in, 85
  amino nitrogen in, 48
  analysis of, for bacteria, 409
  animals producing, 21
  Arnold test of, 406
  aroma of, 22, 56, 58, 66, 77, 126
  ascorbic acid in, 48, 90
  ash in, 44
    (*See also* Ash)
  Ayrshire (*see* Ayrshire milk)
  Babcock test for (*see* Babcock test)

Milk, bacteria in, 102
  beverages from, 126
  bitch's, 51
  bitter, 47, 58, 80, 128
  blue, 129
  boiling point of, 75, 317
  bottler and capper for, 216, 218
  bottles for, 110, 219
  bottling room for, 218
  brucellosis from, 119, 129, 206, 223
  burnt flavor in, 126, 129
  butyric-acid fermentation in, 128
  by-products of, 16, 341
  calcium phosphate in, 68
  calcium salts in, 44, 76, 77, 86, 87
  calories in, 96
  camel's, 21, 51
  caramel flavor in, 126, 129
  carbohydrates in, 84
  carbon dioxide in, 48
  carotene in, 45, 46, 71
  carotenoids in, 46
  carrot flavor in, 129
  casein in, 36
  catalase in, 47
  cat's, 51
  certified, 211, 223
  characteristics of, 21
  for cheese making, 13, 55, 271, 275
  cheese yield from, 270
  chemical nature of, 23
  for children, 97
  cholesterol in, 46
  churned, sampling of, 370
  churning of, 27, 151
  citrates in, 76
  citric-acid fermentation in, 126
  clarification of, 181, 183
  coagulation of, 22, 76, 80, 125, 126, 128, 272
  colloidal nature of, 23, 68
  color of, 21, 22, 45, 46, 54, 66, 71, 72, 116, 129
  colostrum (*see* Colostrum)
  composite sample of, 110, 371
  composition of, 22, 49
    factors influencing, 49, 73, 172, 253
Milk, concentrated, 224
  condensed (*see* Condensed milk)
  for condensing and drying, 14, 15, 55
  constituents of, 21, 68
  consumption of, 18, 19, 423
  containers for, 110, 210, 219
  cooling of, 195, 216, 217
  copper in, 44
  cream line of, 22, 27, 73, 187, 189, 198
  creaming, effect of heat on, 78
  creatine in, 48
  creatinine in, 48
  cultures from, therapeutic use of, 126
  curd tension in, 201
  curdling of, 22, 126, 178
  definition of, 21, 23
  demand for, 17
  delivery of, 211, 214
  diacetyl in, 126
  diastase in, 48
  digestibility of, 92, 98, 129
  dried (*see* Dry milk)
  dry matter in, 23
  economy of, as food, 92, 95
  effect on, of acids, 22, 80
    of feed, 66
    of heat, 22, 75
    of heat stability, 40
    of ultra-violet light, 110
  emulsification of, 200
  energy supplied by, 94
  enzymes in, 47, 80
    (*See also* Enzymes)
  evaporated (*see* Evaporated milk)
  fermentation of, 23, 123
    test of, 405
  fermented, 100, 126, 214, 349
  fibrin in, 41
  filter for, 183
  filtration of, 182
  flavor of, 24, 58, 66, 70, 71, 126 231
  as food, 1, 21, 82, 92
  food value of, 10, 45, 82
  freezing of, 73

Milk, freezing of, point of, 70, 72, 400
  frozen, sampling of, 369
  galactase in, 47
  gas formation in, 126, 128
  gases in, 48
  "germicidal" period of, 123
  globulin in, 41
  goat's, 21, 51, 52, 130
  grades of, 223
  grass flavor in, 129
  gravity creaming of, 27
  Greek theories on, 21
  green, 129
  guaiac test of, 406
  guanine in, 48
  handler of, as source of microörganisms, 122
  health aspects of, 129
  heated, film on, 22
    flavor of, 334
    tests for, 406
  high fat in, 224
  history of industry, 1, 10, 82, 203
  homogenization of, 196
  homogenized, 196, 224, 383
  human, composition of, 51
  hydrogen-ion concentration of, 22, 68, 199, 394
  ice, 293
  for ice cream, 14, 308
  in-the-bottle pasteurization of, 195
  iodine in, 44
  iron in, 44, 45, 87
  irradiation of, 202
  laboratory examination of, 220
  lactase in, 48
  lactic acid in, 22, 69
  lactochrome in, 47, 72
  lactoflavin in, 47
  lactoglobulin in, 41
  lactose in, 23, 41, 50, 51, 53, 54, 59, 62, 68
  lecithin in, 26, 45
  lipase in, 47, 58, 80, 253
  llama's, 21
  malt-like flavor in, 126
Milk, malted, 336
  mare's, 21, 51
  market (*see* Market milk)
  marketing of, 357
  Marschall rennet test for, 402
  mastitis bacteria in, 130
  metallic flavors in, 71
  methylene-blue reduction test of, 403
  microscopic examination of, 22, 410
  mineral balance of, 76
  minerals in, 44, 50, 68, 75, 76, 78, 82, 86, 87, 97
  minor constituents of, 45
  modified, for infants, 51
  musty, 129
  nature of, 21
  neutralization of, calculation of, 364
  niacin in, 48, 49
  nicotinic acid in, 48, 89
  nitrogen in, 48
  non-protein, nitrogenous substance in, 48
  odor of, 22, 33, 58, 70, 77
  off-flavors in, 77, 128
  oxidized flavor in, 71
  pail for, 208
  palatability of, 91
  pantothenic acid in, 48
  pasteurization of, 98, 187, 215, 222, 270, 275
  pasteurized, 224
  peroxidase in, 48
  pH of, 22, 68, 394
  phosphatase in, 48, 406
  phospholipids in, 45
  physical state of, 23, 68
  pigments in, 46, 47, 54, 71, 72
  potato flavor in, 129
  preservatives for, 220, 370
  price of, 11, 354
  producers of, cooperative, 215
  production of, hygienic, 205
  properties of, 21, 68
  protein in, 23, 36, 50, 56, 58, 59, 93
  proteolysis of, 127

Milk, purchase methods for, 214
  purity of, 131
  putrefaction of, 124
  pyridoxine in, 48
  rancid, 58, 80, 199
  raw, 223
  reaction of, 22, 68
  reconstituted, 200, 335, 338
  red, 129
  reductase in, 48
    test for, 403
  reindeer's, 51
  relation of richness of, to food value, 95
  resazurin test of, 404
  riboflavin in, 47, 48, 72, 89
  richness of, 96
  ripening of, for cheese, 275
  ropiness in, 116, 127
  salts in, specific gravity of, 69
  salty taste in, 70
  sample of, preserving, 370
  sampling of, 368
    composite, 371
    tube, 373
  sanitary production of, 205
  sediment in, removal of, 181
    test for, 394
  selling methods for, 354
  separation of (*see* Separation)
  serum solids of, 23
  sheep's, 21, 51
  shipping of, effect of, on fat globules, 27
  skim (*see* Skim milk)
  skimming of, 220
  slimy, 127
  soapy flavor in, 129
  soft curd in, 97, 201, 224
  solids-not-fat of, 23, 61, 69, 93, 308, 390
  sour, sampling of, 370
  as source of income, 10
  sources of microörganisms in, 118
  souring of, 22, 111, 116, 123, 124
  sow's, 51
  specific gravity of, 69, 386, 416
  specific heat of, 73
Milk, stable odor of, 129
  standardization of, 359
  statistics on, 10–13, 423
  Storch test of, 406
  strainers for, 182, 209
  straining of, 181
  stringy, 127, 206
  sugar of (*see* Lactose)
    commercial, 43
    content of, 23, 42
    manufacture of, 346
  sweet curdling of, 115, 128
  tank cars and trucks for, 212
  taste of, 22, 58, 66, 70
  thiamin in, 48, 89
  total solids in, 23, 53
    determination of, 390, 401, 418
  transportation of, 5, 212, 214
  tuberculosis, spread of, through, 129, 131
  turnip flavor in, 129
  undesirable flavors and odors in, 126
  urea nitrogen in, 48
  uric acid in, 48
  uses of, 11
  utensils for, as source of microörganisms, 121
    cleaning of, 209
  viscosity of, 78, 199
  vitamin fortification of, 201
  vitamins in, 48, 87, 202, 224
  water in, 23, 50, 51, 53, 54
  water buffalo's, 21, 51, 52
  watered, detection of, 220, 386, 400
  weight of, per gallon, 387, 416
  whey from, 22
  wholesomeness of, 131
  yellow, 129
  yield of, factors influencing, 56, 57, 62
Milk-borne diseases, 119, 120, 122, 129, 205, 223
Milk fat, absorption of odors by, 32
  action of separator on, 25, 27
  amount of, in milk, 24
  Babcock test for, 133, 146, 411

- Milk fat, in butter, 25, 229
  - in buttermilk, 344
  - butyric acid in, 28
  - butyrin in, 30
  - calculations on, 352
  - capric acid in, 28
  - caprin in, 30
  - caproic acid in, 28
  - caprylic acid in, 28
  - carotene distribution in, 71, 240
  - in cheese, 25, 271
  - in colostrum, 56
  - composition of, 28, 249
    - factors influencing, 33, 54
  - in condensed milk, 316
  - in cream, 24
  - determination of, 410
  - in emulsion, 25
  - in evaporated milk, 25
  - fatty acids in, 28
  - hardness of, 31, 249
  - hydrolysis of, 199
  - in ice cream, 25, 292, 294
  - influence on, of age of cow, 58
    - of breed, 26, 33, 54
    - of feed, 34, 65
    - of plane of nutrition, 35, 36
    - of stage of lactation, 34, 57
  - lauric acid in, 28
  - loss of, in buttermilk, 248, 252
    - in cheese making, 270
    - in skim milk, 154, 173
  - melting point of, 31, 32, 35
    - factors influencing, 31
  - membrane around, 26
  - in milk, 23, 50, 66
    - factors influencing, 23, 51
  - in milk products, 23, 55
  - myristic acid in, 28
  - myristin in, 31
  - nature and structure of, 25
  - nutritive properties of, 96
  - occurrence of, in milk, 249
  - odors absorbed by, 33, 48
  - oil-test churn for, 133
  - oleic acid in, 28
  - palmitic acid in, 28
  - palmitin in, 31
- Milk fat, physical state of, in milk, 25, 68
  - properties of, 31
  - relation of, to churning, 27, 31, 249
    - to flavor of milk, 24
    - to food value, 24
  - Roese-Gottlieb official test for, 410
  - in skim milk, 154
  - softness of, 31
  - solidifying point of, 32
  - solubility of, 32
  - specific gravity of, 32, 69, 134, 152
  - specific heat of, 74, 75
  - stearic acid in, 28
  - structure of, 25
  - volatile acids in, 29, 54
  - water absorption by, 32
  - in whey, 345, 376
- Milk-fat globules, 22, 25, 241
  - absorbed materials on, 26
  - effect on, of freezing, 73
    - of heat, 78
    - of size, in churning, 27, 250
      - in separation, 27
  - rising of, in milk, 152
  - size of, factors influencing, 26
    - shipping, 27
- Milk-plant laboratory, 220
- Milk plants, 4, 215
- Milk powder (*see* Dry milk)
- Milk products, ash in, 44
  - food value of, 3, 44, 98
  - specific gravity of, 386
  - total solids in, determination of, 390, 401
- Milk proteins, 26, 36, 50, 69, 84, 93
- Milk sherbet, 293
- Milk supply, supervision of, 205, 219
- Milker, health of, 208
  - as source of bacteria, 122
- Milking machine, 121, 210
- Mineral matter (*see* Ash)
- Minnesota cream-grading law, 234
- Mojonnier tester, 386, 401, 402
- Molasses, effect of, on milk fat, 35
- Mold, in butter, detection of, 400
    - Wildman test for, 400

Mold, in cream, detection of, 400
    Parsons test for, 234, 400
  hyphae of, 106, 400
  mycelia in butter, 400
  mycelium of, 106
  oidia of, 106
  spores of, 106, 121
  visible, in cream, test for, 234
Mold colonies, photograph of, 116
Mold count, 117
Molds, action of, on milk, 129
  in butter, 262
  in condensed milk, 323
  in dairying, 102
  effect of, on butter and cheese, 116
  growth of, on milk, 124
    factors affecting, 109
  nature and importance of, 106
  proteolysis by, 127
Molecular weights of acids, bases, and salts, 422
Myristic acid, 28, 32
Myristin, 31, 32

N

Neutralization, calculation of, 364
  of cream, for butter making, 234
New Way process for continuous churning, 256
Niacin in milk, 89
Nicotinic acid, addition of, to milk, 202
  function and source of, 89
  in milk, 89
Non-protein, nitrogenous substance, 48
Nutrient "X," 90
Nutrition, part of, in development of dairying, 8

O

Oats, effect of, on milk fat, 35
Odor of milk, 22, 32, 58, 70, 77
Oestrum, 66
Off-flavors in milk and cream, 115, 126, 230
Oil-test churn, 133
Oils, vegetable, effect of, on milk fat, 34
Oleic acid, 28
Olein, 34
Oleomargarine, test for, 407
Oospora lactis, 106
Overrun, of butter, 254, 363
  of ice cream, 303, 367
  (*See also* Butter; Ice cream)
Oxygen in milk, 48

P

Packing stock, 259
Pail, small-mouth, 120
Palmitic acid, 28
Palmitin, 31, 32
Pantothenic acid, 48, 90
Paper milk container, 219
Paraffin tank for cheese, 278
Parfait, 293
Parsons test for mold in cream, 400
Pasteurization, combined vat and flash system of, 235, 237
  continuous-flow system of, 189
  of cream for butter making, 235
  definition of, 187
  effect of, on cream line, 188
    on microörganisms, 114, 188
  efficiency of, 114, 188, 406
  electrical, 111, 196
  flash system of, 189, 235, 275
  as health measure, 222
  high-temperature short-time, 189, 217
  history of, 187
  holding method of, 188, 275
  of ice-cream mix, 301
  in-the-bottle method of, 195
  influence of, on food value, 98
  of milk, 131, 187, 216
    for cheese making, 275
    for starter making, 238
  reasons for, 188, 223
  Rogers system of, 237
  vacreator system of, 236
  vat system of, 235

Pasteurizer, Danish heater-type, 193
  drum-type, 193
  electric, 189, 196
  external-tubular, 189, 194
  film-type, 193
  flash, 192, 235
  glass-lined, 191
  high-temperature, 189, 192, 317
  holding-type, 190
  horizontal-coil, 190, 227
  internal-tubular, 189, 194
  plate-type, 189, 194
  spray-type, 191, 216, 217
  stainless-steel, 191
  vacuum, 235
  vat, 235
  vertical-coil, 191
Pasteurizing room, 216, 217
Penicillium camemberti, 287
Penicillium roqueforti, 284
Pennsylvania test for dairy products, 379
Pepsin, effect of, on casein, 47, 272
Peptonization of milk, 127
Peroxidase, 48, 406
pH, determination of, 394
  of milk, 22, 68
Phenolphthalein, 22, 68, 93, 393
Phenylalanine, 85
Phosphatase in milk, 48
  test for, 406
Phospholipids, 45
  (*See also* Lecithin)
Pigments, of microörganisms, 116
  in milk, 46, 47, 54, 71
Piima, 350
Plastic cream, 24
"Popsicle," 294
Potassium bichromate, 370, 375
Potassium chromate, 397, 399
Potassium hydroxide, molecular weight of, 422
  tenth-normal solution of, 422
Preservatives, 110, 374
Primost (*see* Cheese, Primost)
Process cheese (*see* Cheese, process)
Proline, 85
Propionibacterium shermanii, 283
Protein content of cheese, 271
Protein decomposition by microorganisms, 115, 127
Protein requirements, 84, 93
Proteins, alcohol-soluble, in milk, 41
  calories in, 83
  in cheese, 36, 271
  composition of, 36, 84
  digestibility of, 92
  in foods, 84
  in ice cream, 37
  in milk, 23, 36, 50, 80, 93, 94
  minerals in, 86
  source of, 84
  specific gravity of, 69
  structure of, 85
  vitamins in, 93
Proteolysis of milk, 127
Pseudomonas syncyanea, 129
Pseudomonas synxantha, 129
Ptyalin, 70
Pyridoxine, 48, 90
Pyruvic acid, 89

R

Rancidity, of butter, 30, 31, 47, 253, 261
  of dry milk, 336
  due to enzymes, 47
  of ice cream, 308
  of milk, 58, 80
Reagents, table of tenth-normal solutions of, 422
Reductase, in milk, 48
  test for, 403
Refrigeration, mechanical, 5
Reindeer's milk, composition of, 51
Rennet, action of, on milk, 37, 38, 80, 272, 276, 335
  addition of, to milk for Cheddar-cheese making, 276
  for cheese making, 272, 276
  Marschall test for, 402
Resazurin test, 404
Riboflavin, addition of, to milk, 202
  in cheese, 89
  function of, 89

Riboflavin, in milk, 47, 48, 72, 89, 202
  in whey, 346
Roese-Gottlieb fat analysis, 386, 401, 410
Rogers pasteurizer, 237
Roquefort cheese, 52, 284
  protein in, 36

S

Salt, in butter, 229, 254, 259, 261, 262, 264
  in cheese, 218, 283, 284, 286, 287, 289
  as source of microörganisms, 122
  (*See also* Ash)
Salt analysis of butter, 399
Salt solution, effect of, on microörganisms, 112
Salts, molecular weight of, 420
  tenth-normal solutions of, 420
Sampling (*see* Cream; Milk)
Scandinavian fermented milks, 127, 350
Scarlet fever, 122, 129, 188
Score card, for butter, 261
  for cheese, 281
  for dairy farm, 221, 413
Sediment test, 394
  for butter, 396
  for cheese, 396
  for milk, 395
Senn-process continuous churning, 256
Separation, calculations on, 356
  centrifugal, 151, 157, 229
  control of richness of cream by, 164
  cream, basic principle of, 152, 160
  early development of, 151
  effect of, on fat globules, 27
    on microörganisms in milk, 179
  factors influencing, fat percentage of cream, 166
    variations of, under practical conditions, 172
  gravity, 153
    deep-setting, 154, 179
Separation, gravity, shallow-pan, 153, 174, 226
    water-dilution, 156
Separator, bowl, disc, 158
    hollow-, 158
  centrifugal-action, 157
  cleaning of, 210
  construction of, 160
  course of milk through, 160
  cream screw of, effect of, on richness of cream, 164
    on microflora of milk, 179
  efficiency of, 166, 173
  factory type of, 178
  hand type of, 159, 227
  history of, 5, 151, 157, 226
  influence of, on butter industry, 226
    on dairying, 5
  principle of, 24, 152
Septic sore throat, 119, 122, 129
Serratia marcescens, 127, 129
Serum solids of milk, 23
Shallow pan (*see* Separation, gravity)
Sheep's milk, 21, 51, 284
Sherbets, 293
Shorthorn milk, characteristics of, 33, 53, 54, 59
Silage, bacteria from, 128
Silver nitrate, for butter analysis, 397, 399
  molecular weight of, 422
  tenth-normal solution of, 422
Skim milk, for animal feeding, 100, 342, 343
  ash content of, 342
  Babcock test for, 376
  as by-product, 16, 341
  casein yield from, 344
  Cheddar cheese from, 280
  composition of, 173, 342
  condensed, 343
  Cottage cheese from, 270, 280, 288, 315, 341, 343
  dried, 331, 333, 336, 343
  evaporated, 316
  fat loss in, 154, 173, 342
  food value of, 100

Skim milk, lactose in, 43
  protein in, 342
  specific gravity of, 152, 416
  specific heat of, 75
  sugar in, 342
  test bottle for, 377
  total solids in, 357
  uses of, 13, 341
  vitamin content of, 100
  weight of, per gallon, 416
  yield of, from milk, 341
Sodium alginate, 296
Sodium bicarbonate, molecular weight of, 422
  as neutralizer, 234
  tenth-normal solution of, 422
Sodium carbonate, molecular weight of, 422
  tenth-normal solution of, 422
Sodium chloride, molecular weight of, 422
  tenth-normal solution of, 422
Sodium hydroxide, 422
Soft-curd milk, 199, 201, 224
Soil, microörganisms from, 119, 126
Solids-not-fat of milk, 23
  influence of seasonal variations on, 61
Solutions, tenth-normal, 422
Sonic vibrator, 198
Souring of milk and myth of influence of thunder storms on, 111
Sow's milk, composition of, 51
Soybean meal, effect of, on milk fat, 35
Specific gravity, 70, 386, 416, 418
  of casein, 69
  of colostrum, 56
  of cream, 355, 416
  of dairy products, 386, 416
  of fat of milk, 32, 69, 152
  of fatty acids, 32
  of lactose, 69
  of milk, 69, 386
  of mineral oil, 143
  of proteins, 69
  of salts of milk, 69
  of skim milk, 152, 416
Specific gravity, of sulfuric acid, 135, 411
Specific heat of milk and dairy products, 74
Stable hygiene, 119
Standard units of measure and weight, 417
Standardization of milk and cream, 359
Starter distillate, 239
Starters, for cheese making, 275, 283, 284, 286–289
  for cream ripening, 237
  microörganisms in, 113, 126, 238
  nature and properties of, 237
  preparation and propagation of, 113, 237
Stearic acid, 28
Stearin, 32
Sterilization, 114, 209
Storch test, 406
Strainers, 182, 209
Straining of milk, 181, 209
Straw, microörganisms in, 119
Streptococcus citrovorus, 126, 351
Streptococcus lacticus, 124
Streptococcus lactis, 107, 124, 125, 279, 287, 351
  in Camembert cheese, 287
  in Cheddar cheese, 279
  in cultured buttermilk, 351
Streptococcus liquefaciens, 126, 129
Streptococcus paracitrovorus, 126, 351
Streptococcus thermophilus, 283, 350
Sulfuric acid for Babcock test, 135, 411
Summer complaint, 120, 130
Sweet-cream butter, 230, 234, 258
Sweet curdling of milk, 128
Sweetened condensed milk, 43, 111, 322, 341
  (*See also* Condensed milk)
Swope test for dairy products, 379

T

Tables, conversion, for temperature, 420
  for weights and measures, 417

Taette, 350
Tallow, composition of, 28
Taste and odor of milk, factors influencing, 22, 58, 66, 70, 71
Tests, acidity, 390
  for added water, 400
  alcohol, 404
  amylase, 406
  Arnold, 406
  Babcock, modified, 376
    (*See also* Babcock test)
  for Babcock glassware, 383
  for butter, 396, 407
  for cheese, 378
  composite-sample, 371, 376
  for condensed milk, 382
  Crowe, 380
  cryoscopic, 400
  curd, 400
  for dry milk, 386
  fermentation, 405
  for frozen cream, 369
  Garret-Overmann, 380
  guaiac, 406
  for heated milk, 406
  for homogeneized milk, 383
  hydrogen-ion concentration, 394
  Kay and Graham, 406
  Kohman, 396
  Marschall rennet, 402
  methylene-blue reduction, 403
  Minnesota, 379
  Mojonnier, 386, 401, 410
  mold, 400
  Nebraska, 379
  oleomargarine, 407
  Pennsylvania, 379
  perchloric-acetic acid, 379
  peroxidase, 406
  phosphatase, 406
  reductase, 403
  resazurin, 404
  Roese-Gottlieb, 386, 401, 410
  sediment, 394
  specific-gravity, 386
  Storch, 406
  Swope, 379
  total-solids, 390, 401
Tests, for whey, 376
Tetanus toxin, 116
Thermoduric bacteria, 188, 312
Thiamin, 48, 88, 98, 202
Threonine, 85, 93
Torula amara, 129
Total solids, 53
  determination of, 401, 418, 422
Toxins produced by microörganisms, 116
Trimethylamine, 46
Tryptic enzymes, 201
Tryptophane, 85, 93
Tuberculosis, 119, 120, 129, 130, 206, 223
Typhoid fever, 121, 129, 130, 188

U

Udder, bacteria in, 118
  enzymes in, 129
  interior of, as source of bacteria, 118
  mastitis in, 119
  tuberculosis in, 119
  wiping of, before milking, 120
Ultra-violet light, 110, 202
Undulant fever, 119, 129, 188
  (*See also* Brucellosis)
Urea, 48
Uric acid, 48
Utensils, cleaning and sterilizing of, 111, 121, 209
  as source of microörganisms, 121

V

Vacreator, 236
Vacuum pan, 314, 339
Vacuum-pan pasteurizer, 236
Valine, 85, 93
Velvet beans, effect of, on milk fat, 35
Ventilation, 121
Viscolizer, 196
Viscosity, of buttermilk, 79
  of condensed milk, 79, 317
  of cream, 78, 251

Viscosity, of ice-cream mix, 79, 302
  of milk, 77, 78
    influence of various factors on, 77
  of milk products, importance of, 78
Vitamin A, 87, 98
  addition of, to milk, 202
  relation of, to butter color, 240
Vitamin B-complex, 88, 202
Vitamin C, 90, 98, 202
Vitamin D, 90, 201
  concentrates of, addition of, to milk, 201
  function of, 90
  source of, 91
Vitamin-D milk, preparation of, 224
Vitamin E, 91
Vitamin G, 89
Vitamin K, source of, 91
Vitamin PP, 89
Vitamins, 87–91
  addition of, to milk, 201
  in butter, 98, 240
  in milk, 48, 88
  in skim milk, 100

W

Water, adulteration of milk with, 73, 400
  in foods, 23, 83
  in milk, 23, 83
  physical state of, in milk, 68
  as source of microörganisms, 122
Weeds, relation of, to butter flavor, 128
Weights and measures, per gallon of cream, 416
  tables for conversion of, 417
Westphal balance, 387
Wheat gluten, effect of, on milk fat, 35
Whey, acetone from, 346
  alcohol from, 346
Whey, as animal food, 345
  ash content of, 45
  Babcock test of, 376
  butter, 259, 345
  butyl alcohol from, 346
  cheese, 16, 40, 276, 345
  composition of, 345
  condensed, 315, 346
  dried, 16, 332, 346
  fat in, 28, 345
  food value of, 40
  lactose from, 346
  from milk, 22
  Primost from, 40, 346
  riboflavin in, 346
  specific heat of, 74
  testing of, 376
  use of, 346
  vinegar from, 346
Whipping cream (*see* Cream)
Wildman test for mold in butter, 400
Wisconsin, cheest factories in, 14

X

Xanthophyll in corn, 47

Y

Yeast, irradiated, fed to cows, 201
Yeast count, 117
Yeasts, 105
  in butter, 261
  in condensed milk, 323, 340
  in dairying, 102
  effect of acidity on, 110
  in fermented milk, 349
  growth of, in milk, 124
  milk fermentation by, 126, 129
  pigment-producing, 114, 118
Yoghurt, 350

Z

Zein, protein of corn, 85

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